

CaL. Lab.

MS 94

POWER SUPPLY

MODELS

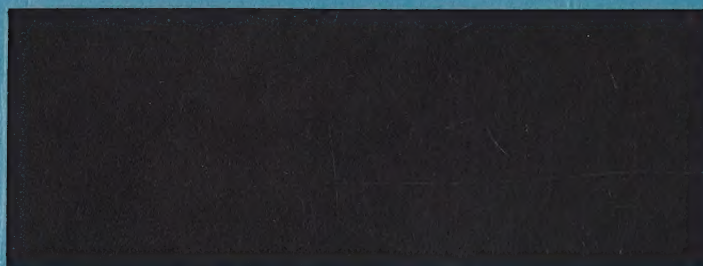
SP-2701, SP-2711, SP-2721, SP-2731

595-1744

**OPERATION/SERVICE
MANUAL**

HEATH

Schlumberger



POWER SUPPLY

MODELS

SP-2701, SP-2711, SP-2721, SP-2731

595-1744



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INTRODUCTION

This Power Supply is a precision instrument that provides laboratory-grade regulation of output voltage and output current. Both front and rear output terminals are isolated from chassis ground and thus can be referenced to supply either a positive or negative voltage, or be allowed to float above ground. The large 3-1/2 digit (1999), two-decade, auto-ranging digital display can be switched to read output voltage or load current. Its patented*, dual-slope, integration technique minimizes temperature and drift errors.

Load current limiting is determined by a front panel control or can be programmed by an external voltage source. In either mode, the output is completely protected from a load short circuit.

Coarse and fine controls allow precise control of the output voltage level. In addition, this can be set while the Power Supply is in the Standby position. Output voltage can also be determined through two external programming modes. The first method uses a reference voltage; the second requires only an external variable resistor.

The output voltage circuit employs a conservatively-designed, fully-dissipative regulator. This allows indefinite short-circuit operation with no Power Supply damage. The output is also protected from inadvertently applied voltages through blocking and clamp diodes. Also, the load is protected against open remote-sensing leads by limiting the output voltage increase to less than 1.5 volts.

Voltage and current are displayed by a large 0.55" (14mm) digital display. Because of its large size and brightness, it can be easily read over a large viewing area and in brightly lit rooms. The "nonflicker" display updates seven times per second to allow quick setability.

Additional features include:

- Remote sensing.
- Dual-tracking with two Power Supplies.
- Auto-series operation.
- Auto-parallel operation.
- 120/240 AC power selectivity.

Printed circuit boards, wire harnesses, open wiring, and careful design makes any servicing quick and simple. Also, the display circuitry unplugs to allow separate factory servicing without disabling the main power supply. Full calibration is easily accomplished with "built-in" standards that insure the Power Supply will perform to its specifications. The Manual provides extensive operation, troubleshooting, and service information.

*U.S. Patents 3,051,939 and 3,316,547.

SPECIFICATIONS

Specifications determined by NEMA standards (PY1-1972)
after 30-minute warmup period.

GENERAL

Output

Voltage: SP-2701 0-60VDC.
SP-2711 0-30VDC.
SP-2721 0-15VDC.
SP-2731 0-7.5VDC.

Current: SP-2701 0-1.5A.
SP-2711 0-3A.
SP-2721 0-5A.
SP-2731 0-10A.

Load Regulation

Voltage: $\pm 0.05\%$, +1 mV.
Current: 0.10%, +3.5 mA.

Line Regulation

Voltage: $\pm 0.05\%$, +1 mV.
Current: $\pm 0.10\%$, +1 mA.

Ripple and Noise

1 mV rms.
0.03% of full
rated output peak-to-peak.

Temperature Coefficient at Output Terminals
(10°C to 40°C ambient)

Voltage: $\pm (0.01\% + 1.5 \text{ mV})/^{\circ}\text{C}$.
Current: $\pm (0.05\% + 1 \text{ mA})/^{\circ}\text{C}$.

Stability at Output Terminals

Voltage: $\pm (0.01\% + 1 \text{ mV})/\text{hr}$.
Current: $\pm (0.05\% + 1 \text{ mA})/\text{hr}$.

Load Transient Recovery

For a load $\leq 5\text{A}$, output
voltage shall be in regulation
band within 50 μS .

Overshoot

Zero overshoot when switching
power on or off (standby switch
on).

Output Protection	Up to 200V (150V for SP-2721 and SP-2731) against positive applied voltages. 10A diode clamp for negative applied voltages. Indefinite short circuit protection.
Load Protection	<1.5 VDC change with open sense leads.
Programming Frequency Response	DC to 100 Hz, ± 2 dB.
Programming Transient Response	0.1 mS for low to high load current changes, 1 mS for high to low load current changes. Load resistance must be less than 10 times rated output voltage divided by rated output current.
Programming Mode	Voltage: 0 to rated voltage with 0 to 5.0 VDC applied. 0 to rated voltage with 0 to 5000 Ω external resistor. Current: 0 to rated current with applied voltage of 1 volt/ampere (0.1 volt/ampere for SP-2731).
Power Requirements	110-130 V, 50/60 Hz, 200 watts. (220-260 V by changing internal switch and fuse).
Fuse	120V Operation: 3-ampere. 240V Operation: 1-1/2-ampere.
Dimensions	5.5" high, 15" wide, and 13.5" deep. (13.97 cm high, 38.1 cm wide, 33.02 cm deep).
Weight	30 lbs. (13.6 kgs).

DISPLAY

Voltage/Current Readout (switchable)	3-1/2 digit (1999), auto-ranging, digital meter.
Readout Ranges	Voltage: 0.00-19.99 20.0-60.0 Current: .000-1.999 2.00-10.00

Readout Accuracy	Voltage: $\pm 0.5\% \pm 1$ count using laboratory standards. $\pm 1.0\% \pm 1$ count using built-in standards.
Readout Rate	Current: $\pm 1.0\% \pm 4$ counts using laboratory standards. $\pm 1.5\% \pm 4$ counts using built-in standards.
Readout Response Time	7 per second (60 Hz). 6 per second (50 Hz).
Readout Response Time	2 seconds to within 5 counts.
Temperature Coefficient (as displayed) (10°C to 40°C)	Voltage: $\pm (.025\% + 2 \text{ mV})/^{\circ}\text{C}$. Current: $\pm (.065\% + 1.5 \text{ mA})/^{\circ}\text{C}$.
Stability (as displayed)	Voltage: $\pm (0.01\% + 1 \text{ mV} + 1/2$ count)/hr. Current: $\pm (0.01\% + 1 \text{ mV} + 1/2$ count)/hr.

PERFORMANCE FEATURES

Voltage Control	Front panel variable, zero to full output, coarse and fine controls.
Current Control	Front panel variable, zero to 100% control.
Operating Modes	Constant voltage, constant current, auto-series, dual-tracking, and auto-parallel.
Programming Modes	Voltage control of voltage, resistance control of voltage, and voltage control of current.
Outputs	Front panel: +V, -V, and chassis ground binding posts. Rear Panel: +V, -V, chassis ground, remote sense, and parallel and series programming barrier strip terminals.
Output Protection	Output protection against circuit shorts and applied voltages.
Load Protection	Load protected from open sense leads.
Specifications	Determined by NEMA standards PY1-1972.

DISPLAY FEATURES

Auto-Ranging	Automatic up-ranging to 200 ± 1 count when increased from zero through 1999. Automatic down-ranging to 1790 ± 5 counts when decreased from full scale through 180. Automatic decimal point placement.
Resolution	Voltage: 10 mV below 20 volts; 100 mV above 20 volts. Current: 1 mA below 2.0 A; 10 mA above 2 A.
Reading Modes	Auto-ranging; or high range only (using internal jumper).
Digits	0.55 inches (14 mm) high, 7-segment, planar; 1999 maximum display.
Viewing Angle	Greater than 45° in any direction.

The Heath Company reserves the right to discontinue products and to change any specifications at any time without incurring any obligation to incorporate new features in products previously sold.

VERIFICATION

True evaluation of the performance characteristics of a power supply require careful testing methods. The following general procedures are presented if you wish to verify the Specifications.

1. Terminate all test leads with spade-type lugs or solder connections. Alligator clips and other similar connectors may inject undesirable contact resistance.

2. Use twisted wire-pairs or shielded cable for test leads. Stray magnetic fields can introduce unwanted signals.
3. Check for system-generated noise and ripple after hookup. Ground loops generate undesirable current paths.
4. Connect all test instruments at the power supply sense terminals. Erroneous readings can be obtained if the measurements are made at the load.

Voltage Programming of Output Voltage — Where the output voltage of the Power Supply is controlled by a 0-5 volt voltage source connected to the programming terminals, instead of by the front panel VOLTAGE control.

Resistance Programming of Output Voltage — Where the output voltage is controlled by a variable resistance (0-5000 Ω) connected to the programming terminals, instead of by the front panel VOLTAGE control.

Voltage Programming of Current — Where the output current is controlled by an external voltage source connected to the programming terminals.

Several "Operational Examples" are given in this section of the Manual to help you become more familiar with the controls and various programming methods. It may also be helpful if you read the "Circuit Description" and examine the Schematic before you operate this Power Supply.

If you intend to operate this Power Supply near the auto-ranging crossover point (19.99 volts or 1.999 amperes), you may wish to hold the display in the high range. This will reduce resolution, but insure a stable display. Refer to Figure 3-2 on fold-out from Page 34 and shift the RANGING jumper wire, on the display circuit board, from the AUTO pin to the HI ONLY pin. This jumper wire is accessible through the left side panel of the Power Supply.

OPERATING PROCEDURE

Examine the rear panel terminals (the screws must be tight) before you operate the Power Supply. Initially, this instrument is programmed for local sensing and front panel power output. It will be necessary to change the rear panel connections to operate in other modes. Wiring instructions for other configurations are presented in the "Examples" later in this section. Always operate the Power Supply in the following sequence.

1. Check the rear panel terminals for proper setup.
2. Press the PWR switch to ON. The display will light.
3. Press the VOLT pushbutton, and adjust the COARSE and FINE VOLTAGE controls for the desired output voltage.
4. Short the output terminals.
5. Set the DC ON/STANDBY switch to DC ON.
6. Press the AMP pushbutton, and adjust the CURRENT control for the desired output current limit level.
7. Set the DC ON/STANDBY switch to STANDBY.
8. Remove the short and connect the load.
9. Set the DC ON/STANDBY switch to DC ON.

NOTES ON OPERATION

The following notes are provided as a general guide and will not satisfy every application. Therefore, it may be necessary to experiment for optimum results. CAUTION: Turn the AC power off before you change jumper clip positions.

WIRE RATING

Always select a wire sufficient in size to carry the current that would flow should the load short circuit. Refer to the "Load Wire Rating Chart" (Table I) on Page 16.

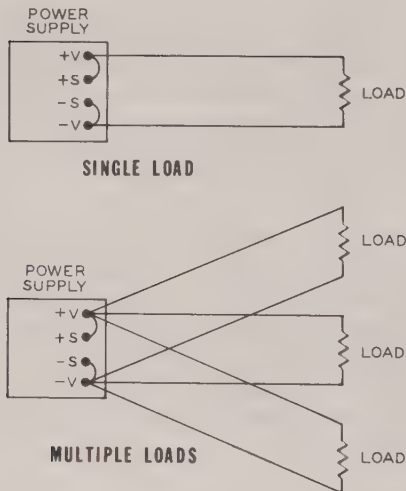


Figure 1-3

LOAD CONNECTIONS

If more than one load is connected to the Power Supply, use a separate pair of wires for each load and connect them directly to the Power Supply (See Figure 1-3).

When remote sensing is used, connect each load to a common point as close to the load as possible. Connect the sense leads to the same common point as shown in Figure 1-4.

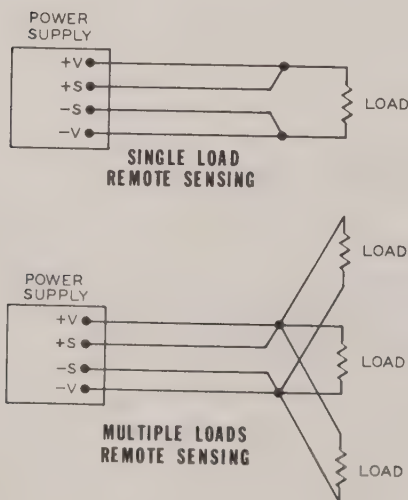


Figure 1-4

LOAD DECOUPLING

To reduce high frequency mutual coupling between multiple loads fed from the same power supply, connect a decoupling capacitor across each pair of load leads at the load. The high frequency impedance of the capacitors must be lower than the wire impedance. In addition, the capacitor lead length must be as short as possible.

GROUND SYSTEM

Often it is desirable, or necessary, to reference the Power Supply to ground potential. To avoid ground loop problems, there must be only one ground return point. One side of the supply line should be considered the DC common point. [If it is a positive supply, the DC common point is the negative (-V) terminal.]

With single and multiple loads that are isolated from ground, the DC common should be grounded at the point where the sense lead is connected. Figure 1-5 shows the ground method with local sensing, and Figure 1-6 illustrates the ground method with remote sensing.

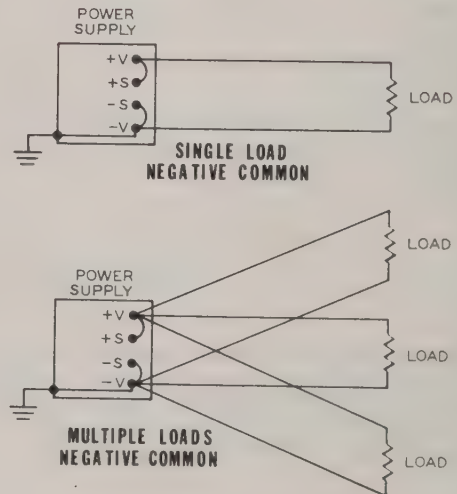


Figure 1-5

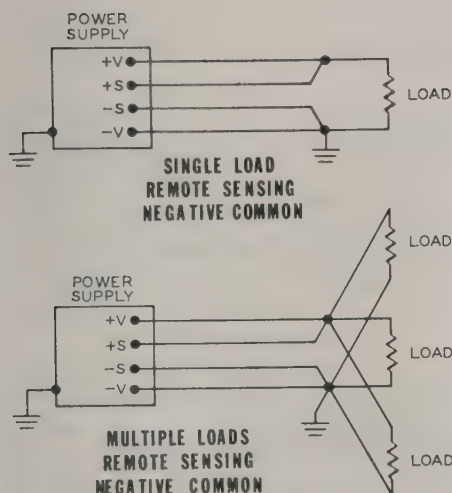


Figure 1-6

If one of the loads (in a multiple load system) is already referenced to ground, use that point as the DC common. Figure 1-7 illustrates the various configurations.

NOTE: Use a separate Power Supply for each grounded load. Ground loops generally occur when there is more than one connection of the DC common (+ or -) to earth (power line) ground, or when the common connections in a multiple load circuit are not all returned to one common point. Any "circulating" ground currents that then occur can produce noise in the DC circuit(s).

Whenever two or more Power Supplies are used together, they should be referenced to the same DC common ground, as you would for multiple loads.

NOTE: The -V terminal is coupled to chassis ground through a 0.1 microfarad capacitor. This must be taken into consideration with many applications; such as where earth (power line) ground loops might be a problem, or where the Power Supply is used for floating operation in high impedance circuits.

Two-wire shielded cable (as might be used for sense leads) must be grounded at only one end.

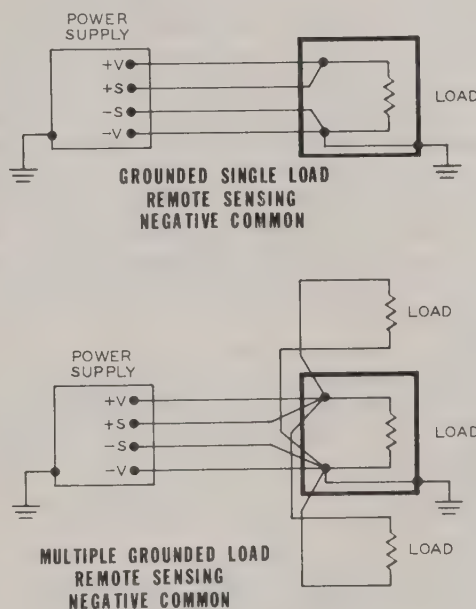


Figure 1-7

OPERATIONAL EXAMPLES

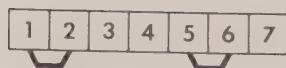


Figure 1-8

EXAMPLE #1

Local Sensing

Two terminals on the rear panel barrier strips are used to monitor the load voltage for feedback to the voltage regulator. With local sensing, the voltage is monitored as the Power Supply. If the front panel binding posts are connected to the load, install the four jumper clips to the two barrier strips as shown in Figure 1-8. If the load is connected to the barrier strips as shown in Figure 1-9, install the four jumper clips as shown in Figure 1-9. CAUTION: Whenever the load is connected to the barrier strips, always use terminals #3 and #10 (not #2 and #9).

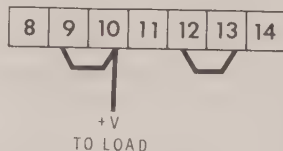
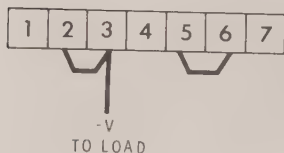


Figure 1-9

EXAMPLE #2

Remote Sensing

In applications where the load is remote from the Power Supply, it is best to monitor the voltage at the load for optimum regulation. Connect the load to the front binding posts or to terminals #3 and #10, as shown in Figure 1-10. Wire size must be large enough to insure a drop of less than 0.5 volts per lead at the load current drawn. Refer to "Wire Loading" on Page 16. Connect the sense leads to the power leads at the load. Use a twisted-pair or a coaxial cable for the sense leads to reduce stray noise pickup. Note that the jumper clips between terminals #5 and #6 and terminals #12 and #13 are not removed.

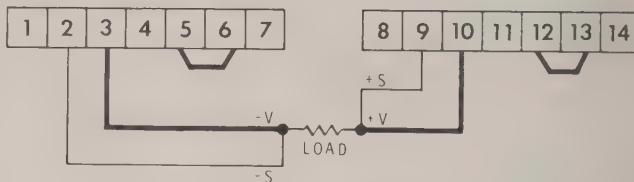


Figure 1-10

EXAMPLE #3

Voltage Programming of Output Voltage

Remote control of the output voltage is easily accomplished with a 0 to 5-volt source. An input of 0 volts will produce a 0-volt output from the Power Supply while a 5-volt input will produce the rated maximum output from the Power Supply. Any input level between 0 and 5 volts will produce a proportional output level. Keep in mind that a programming signal with a fast rise time will produce some overshoot in the output level. The front panel VOLTAGE control is disabled in this program mode.

CAUTION: Programming voltages in excess of 5 volts can cause the output to go approximately 30% higher than rated output. This will not damage the Power Supply, but it is not recommended as ripple will be excessive and regulation will be poor.

Refer to Figure 1-11 for a typical voltage programming setup. Remove the jumper clip from between terminals #5 and #6. Then connect the voltage source to terminals #2 (negative lead) and #6 (positive lead). Use a twisted wire pair or a coaxial cable, to reduce noise pickup. All other jumper clips remain installed. Connect the load to either the front panel binding posts or to terminals #3 and #10 (as shown). NOTE: For local sensing of the front panel binding posts, the sense jumper clips must be connected to terminals #1 and #2, and terminals #8 and #9.

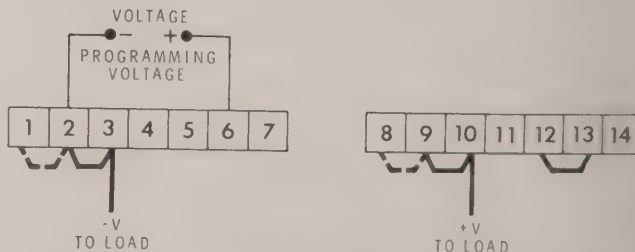
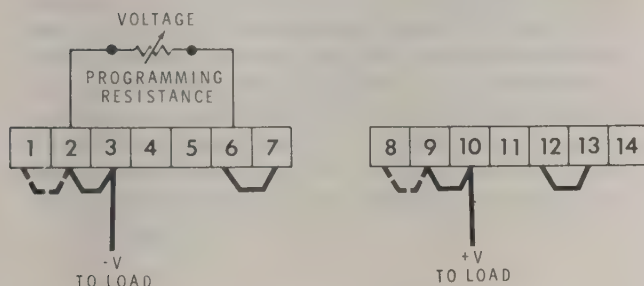


Figure 1-11

EXAMPLE #4**Resistance Programming of Output Voltage**

Output voltage can be programmed by an external control with a variable resistance from 0 to 5000 ohms. A zero resistance will produce a zero output level while a resistance of 5000 ohms will produce the rated maximum output from the Power Supply. Any program resistance between 0 and 5000 ohms will produce a proportional output level. The front panel VOLTAGE control is disabled in this program mode.

CAUTION: A programming resistance greater than 5000 ohms can cause the output to go approximately 30% higher than rated output. This will not damage the Power Supply, but it is not recommended as ripple will be excessive and regulation will be poor.

**Figure 1-12**

Refer to Figure 1-12 for a typical resistance programming setup. Remove the jumper clip from between terminals #5 and #6 and connect it between terminals #6 and #7. Connect the program control between terminals #2 and #6 with a twisted wire pair or a shielded cable to reduce noise pickup. All other jumper clips remain installed. Connect the load to either the front panel binding posts or terminals #3 and #10 (as shown). **NOTE:** For local sensing of front panel binding posts, the sense jumper clips must be connected to terminals #1 and #2, and terminals #8 and #9.

After the Power Supply has been set up for programmed resistance, it must be calibrated to the external control. To calibrate your Power Supply perform the following steps. **NOTE:** This will not affect normal calibration or operation.

1. Position the controls and switches as indicated:

PWR switch — Off (out).

VOLT switch — On (in).

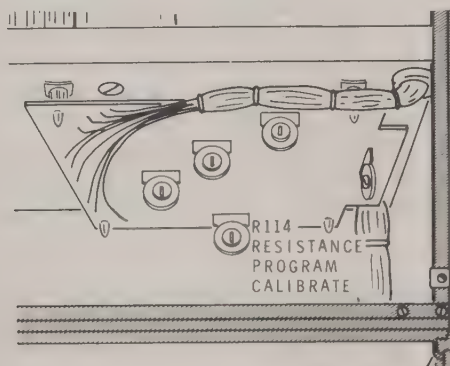
AMP switch — Off (out).

DC ON/STANDBY switch — STANDBY (down).

CURRENT control — Fully counterclockwise.

VOLTAGE control — Disregard (control disabled).

2. Insert the line cord plug into the proper power outlet and depress the PWR switch. The display will light.
3. Allow the Power Supply 30 minutes to warm up before you begin calibration.
4. Remove the six screws from the top cover and remove the top cover.
5. Turn the front panel CURRENT control to the center of rotation.
6. Adjust the external program resistance to maximum (5000 ohms).

**Figure 1-13**

7. Refer to Figure 1-13 and adjust R114, the RESISTANCE PROGRAM CALIBRATE control, for a maximum rated output indication on the Power Supply display.
8. Switch the Power Supply off and disconnect the line cord plug.
9. Reinstall the top cover.

The Power Supply is now calibrated to the external program resistance.

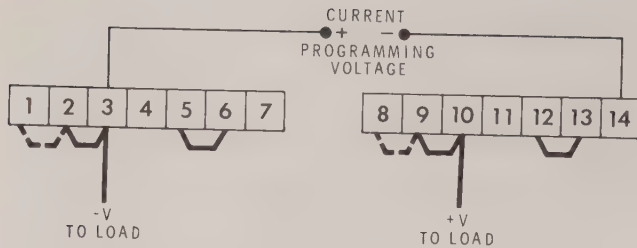


Figure 1-14

EXAMPLE #5**Voltage Programming of Load Current**

Load current limiting can be controlled by an external voltage source. The relationship between the current-limiting level and the external voltage applied is 1 ampere/1 volt (10 amperes/1 volt for the SP-2731).

Figure 1-14 shows a typical setup with the load connected to terminals #3 and #10. However, the front panel binding posts can be used when the two sense jumper clips are reconnected to terminals #1 and #2, and terminals #8 and #9. The positive programming voltage is connected to terminal #3 and the negative to terminal #14. The front panel CURRENT control must be positioned fully counter-clockwise. If it is not, there will not be a proper relationship between current limiting and the programming voltage.

CAUTION: Output current can be programmed beyond the rated level. If this is allowed to continue for more than a few seconds, the driver and power transistors will overheat and fail.

EXAMPLE #6**Series Operation (Voltage Doubler)**

Two Heath Power Supplies of the same voltage and current rating can be connected in series to produce a voltage of up to twice the rating of a single Power Supply. The two units operate in a master-slave configuration and the display indications of both units must be added together for correct output voltage. However, either the master or slave unit can be used to indicate the correct current level.

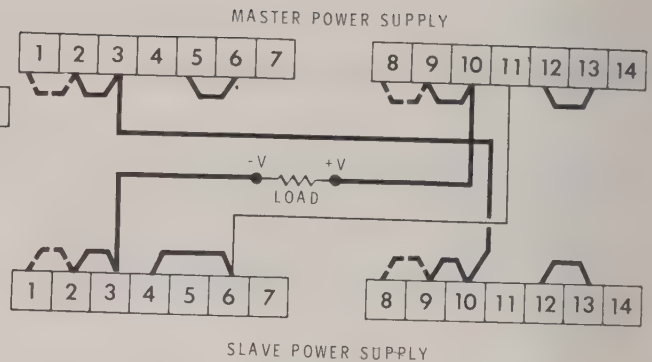


Figure 1-15

Figure 1-15 shows a typical series setup with the load connected to terminals #3 of the slave unit and #10 of the master unit. If the front panel binding posts are used, reconnect the sense jumper clips to terminals #1 and #2, and terminals #8 and #9 of both Power Supplies. Note that the jumper clip between terminals #5 and #6 has been removed on the slave unit and a jumper wire connected between terminals #4 and #6. Control interface is supplied through the wire connected between terminal #6 of the slave unit and terminal #11 of the master unit. The front panel CURRENT control on the slave unit must be turned fully clockwise to allow the master unit full control of current limiting.

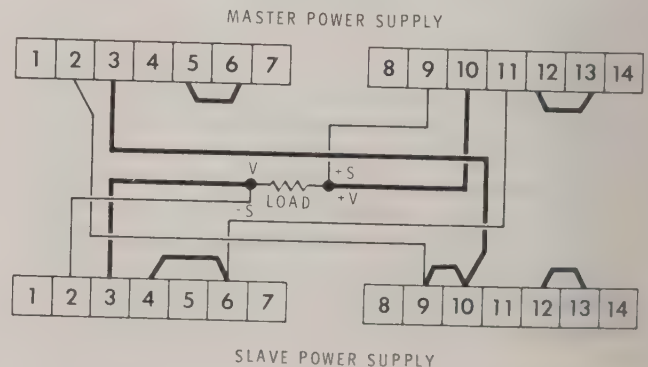


Figure 1-16

Figure 1-16 shows the correct method for connecting remote sense leads to the load. Note that the master negative sense terminal is connected to the slave positive sense terminal and the sense jumper clip remains connected between terminals #9 and #10 on the slave unit.

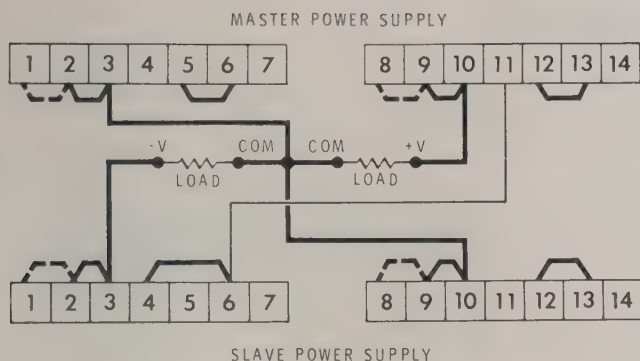


Figure 1-17

EXAMPLE #7**Series Operation (Dual-Tracking)**

A variation in the series setup produces a dual tracking Power Supply with independent current control for each supply. Figure 1-17 shows that the only change from a typical voltage doubler is that the common line now serves as the reference to the positive voltage from the master unit and the negative voltage from the slave unit.

Figure 1-18 shows the correct method for connecting the remote sense leads to the load.

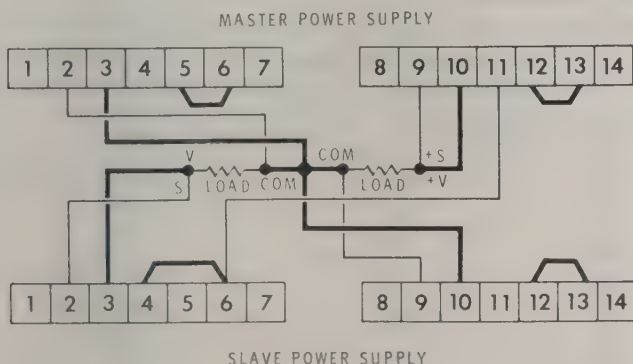


Figure 1-18

EXAMPLE#8**Parallel Operation**

You can connect up to six* Power Supplies of the same rating in parallel to provide greater current capacity. However, the total current output must be derated 20% regardless of the number of units in parallel. While the master unit controls the voltage level, each Power Supply regulates its own current. Although, for most applications, the CURRENT control is set fully clockwise.

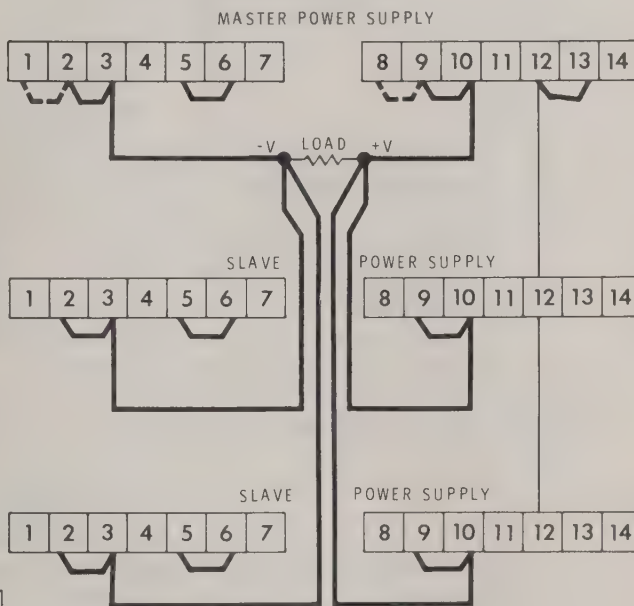


Figure 1-19

Figure 1-19 illustrates a typical parallel setup with three Power Supplies. The load is shown connected to terminals #3 and #10 of each unit. The front panel binding posts can be used after the sense jumper clips are repositioned to terminals #1 and #2, and terminals #8 and #9 of the master unit. All the jumper clips shown on each slave unit are left in position as a convenience. They have no effect on the operation. Terminal #12 of each slave unit is the control input and must be connected to terminal #12 of the master unit. Note that the output of each unit is connected directly to the load for reduced wire loading. For remote sensing, use terminals #2 and #9 of the master unit only.

*Six SP-2701
Four SP-2711
Three SP-2721
Two SP-2731

WIRE LOADING

Table I provides the necessary data to connect your load to the Power Supply and maintain specific regulation. The "maximum current rating" is based on a single insulated copper wire with a wire temperature rise of approximately 60°C. Ambient temperature may be as high as 40°C. For two wires (twisted or bonded), use 80% of the maximum current rating specified. Wire lengths greater than 25 feet should have additional filtering added at the load. The "voltage drop constant" is based on a maximum voltage drop of 0.5 volts across one lead of the load wires, and a maximum wire temperature of 120°C. The following "Examples" illustrate its use.

EXAMPLES:

1. A load current of 10 amperes is to be carried over a distance of 50 feet.

$$\begin{aligned} \text{CURRENT (AMPS)} \times \text{DISTANCE (FEET)} &= \\ \text{VOLTAGE DROP CONSTANT} & \\ 10 \times 50 &= 500 \end{aligned}$$

The current of 10 amperes indicates that you should use 20 gauge or larger wire. However, the voltage drop constant indicates that 8 gauge or larger must be used.

2. A load current of 5 amperes is to be carried, and 14 gauge wire is available.

$$\frac{\text{VOLTAGE DROP CONSTANT}}{\text{CURRENT (AMPS)}} = \text{LENGTH (FT.)}$$

$$\frac{156.3}{5} = 31.25$$

The load can be up to 31.25 feet away from the Power Supply.

3. The load is 25 feet from the Power Supply, and 22 gauge wire is available.

$$\frac{\text{VOLTAGE DROP CONSTANT}}{\text{LENGTH (FEET)}} = \text{CURRENT (AMPS)}$$

$$\frac{22.73}{25} = 0.91$$

A load current of up to 0.91 amperes can be carried.

TABLE I
LOAD WIRE RATING CHART

AWG WIRE GAUGE NUMBER	MAXIMUM CURRENT* (AMPS)	VOLTAGE DROP CONSTANT CURRENT (AMPS) X LENGTH (FEET)
24	4.7	17.61
22	9.3	22.73
20	14.7	36.50
18	21.3	76.92
16	27.3	97.09
14	42.7	156.3
12	53.7	247.5
10	73.3	381.7
8	97.3	681.2

*Based on EIA Standard RS-214.

IN CASE OF DIFFICULTY

INTRODUCTION

This part of the Manual will help you locate and correct any difficulty which might occur in your Power Supply. The information is divided into three sections. The first section contains suggestions of a general nature in the following areas:

- A. Bench-testing precautions.
- B. Repair techniques.

The second section consists of a "Basic Power Supply Troubleshooting Chart." This chart covers the "power" portion of the Power Supply. It calls out specific problems that may occur and lists one or more conditions or components that could cause each difficulty. Capacitor C numbers, transistor Q numbers, etc., are identified in this chart by the same numbers that are used on the Schematic

diagram. "Circuit Board X-Ray Views" (beginning on Page 48) are also provided to help you locate the components.

The third section consists of a "Display Troubleshooting Program" that contains "Waveforms Test Chart" to help you determine the trouble area in the display circuit.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

If you are unable to repair the display circuits in your Power Supply, DO NOT return the entire Power Supply for service. Unplug the display circuit board assembly and remove it from the Power Supply. Then return this assembly for service. The Power Supply will function without the display circuit assembly.

GENERAL

BENCH TESTING

WARNING: The full AC line voltage and high voltage DC is present at several points in the Power Supply. Be careful to avoid personal shock when you work on the Power Supply. Refer to Figure 4-1 on Page 40.

- Be cautious when you test the transistors and integrated circuits. Although they have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage and current than are other circuit components.
- Be careful so you do not short any terminals to ground when you make voltage measurements. If the probe should slip, for example, and short out a bias or voltage supply point, it may damage one or more components.
- Do not remove any components while the Power Supply is turned on.
- When you make repairs to the Power Supply, make sure you eliminate the cause as well as the effect of the trouble. If, for example, you should find a damaged resistor, be sure you find out what caused the resistor to become damaged. If the cause is not eliminated, the replacement resistor may also become damaged when the Power Supply is put back into operation.
- Refer to the "X-Ray Views," and the "Schematic" to locate the various components.
- Use a high impedance voltmeter to make any voltage measurements.
- Use the $-V$ or $-SENSE$ terminal for circuit ground when you make any voltage measurements on the control circuit board. Use the shield wire connected to hole BC on the display circuit board for any voltage measurements on the display circuit.
- Always check the ± 11 volt supply on the control circuit board for proper level before you attempt to troubleshoot this instrument.
- Connect the rear panel jumper clips for normal operation, front panel output.
- Avoid repeated flexing of the harness wires. It is best to position the circuit board you are testing above the chassis and leave it there throughout the servicing procedure.
- If you remove IC314 or IC315 (on the display circuit board) DO NOT TOUCH THEM TO ANYTHING that you are not already touching with your other hand. This will prevent static electricity from being discharged through these parts and possibly damaging them.

REPAIR TECHNIQUES

Components

Faulty resistors or capacitors should first be clipped from component leads from the circuit board, heat the solder on the foil and allow the lead to fall out of the hole. Preshape the leads of the replacement part and insert them into the holes in the circuit board. Solder the leads to the foil and cut off the excess lead lengths.

Transistors can be removed in the same manner as previously described. The replacement transistor must be installed with its leads in the proper holes. Then quickly solder the leads to avoid heat damage. Cut off the excess lead lengths.

CAUTION: On several areas of the circuit boards, the foil patterns are quite narrow. When you unsolder a part for checking or replacement, avoid excessive heat while removing the part. A suction-type desoldering tool will make part removal easier.

Foil Repair

A break in a circuit board foil can be bridged by soldering across the break. Large gaps in the foil should be bridged with a length of bare wire. Lay the wire across the gap and solder each end to the foil.

Plated-Through Holes

Some of the component and lead holes on the display circuit board have a metallized layer of plating which connects the foil on one side of the circuit board to foil on the other side. Sometimes, due to a component removal, this plating is broken and the circuit is opened. A simple ohmmeter test will verify, at foil points, if the plated-through hole is good. If it shows anything but a short (less than 1Ω), solder the component lead on both sides of the circuit board at that hole.

BASIC POWER SUPPLY TROUBLESHOOTING CHART

NOTE: This Troubleshooting Chart lists problems only in the basic power supply. If there is any question as to whether the display circuitry may be the cause of a problem, unplug the display circuit assembly wire harness connection and use an external voltmeter to verify operation of the basic "Power Supply."

PROBLEM	POSSIBLE CAUSE
Blows fuse.	1. Diodes D1 or D2 shorted to chassis. 2. Filter capacitors C2 (or C3). 3. Display circuit short-circuited.
No output, display not illuminated.	1. Fuse open. 2. Power transformer. 3. Switch SW1 or SW2 defective.
No output, display illuminated.	1. Output shorted. 2. Control R152 improperly adjusted. 3. Barrier strip jumper clips improperly installed. 4. Transistor Q107 or Q103 shorted. 5. Switch SW4, or SW5. 6. Diodes D103, D114, or D118 defective. 7. Diode D11 open. 8. Diode D21 shorted. 9. Defective voltage regulator circuit if output goes high when jumper clip across terminals 12 and 13 is removed. (Turn power off before you remove jumper clip).
Voltage excessively high (over rated output level).	1. Transistor Q107 open. 2. Transistor Q1, Q2, or Q3 (or Q4) shorted. 3. Diode D131 defective. 4. Barrier strip jumper clips improperly installed. 5. Defective voltage regulator circuit if output goes low when jumper clip across terminals 12 and 13 is removed. (Turn power off before you remove jumper clip.)

PROBLEM	POSSIBLE CAUSE
No current control.	1. Integrated circuit IC101 defective. 2. Diode D151 open. 3. Control R152 adjusted incorrectly. 4. Q113.
Oscillation on the output with no load.	1. RC circuit defective: R121-C121, R126-C126, R128-C128, or R129-C129. 2. Capacitor C11, C117, C122 or C141. 3. R152 improperly adjusted.
Oscillations on the output with a load. Current limiting set higher than load current.	1. RC circuit defective: R121-C121, R126-C126, R128-C128, or R129-C129. 2. Capacitor C11, C117, C122, or C141. 3. Many types of loads, especially circuits using active devices, will react with the complex output impedance of the Power Supply to produce oscillations; usually of low amplitude and high frequency. Adding bypass capacitors to the load circuit, or in some manner changing the impedance characteristics should eliminate the oscillations.
Oscillations on the output with a load. Current regulator is regulating the load current.	1. Capacitor C11, C151, or C152 defective. 2. Resistor R154 open.

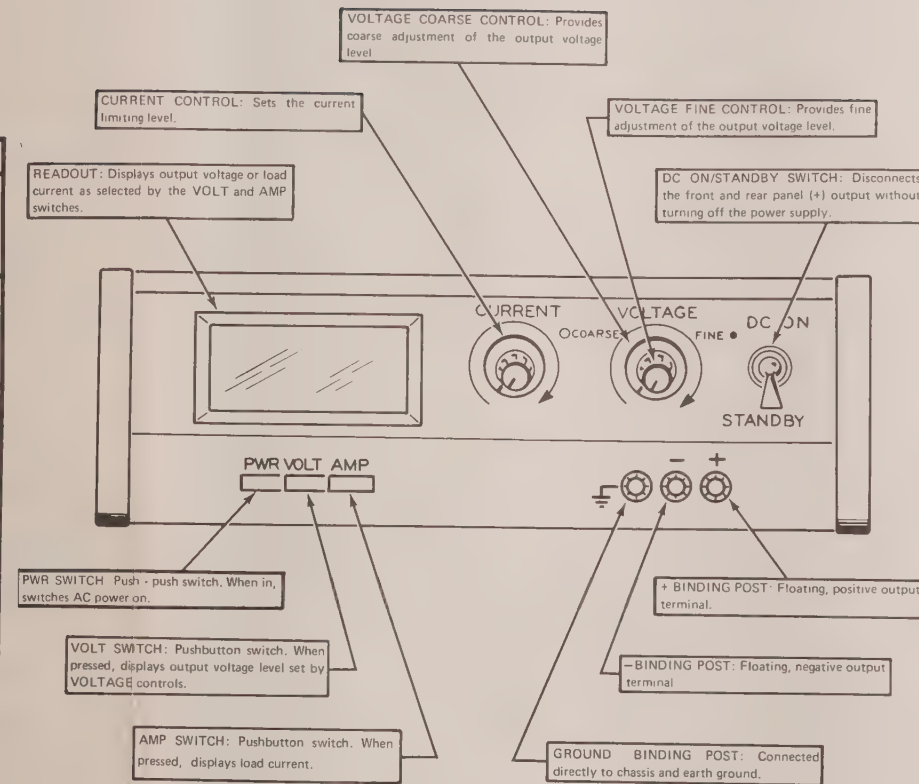


Figure 1-1

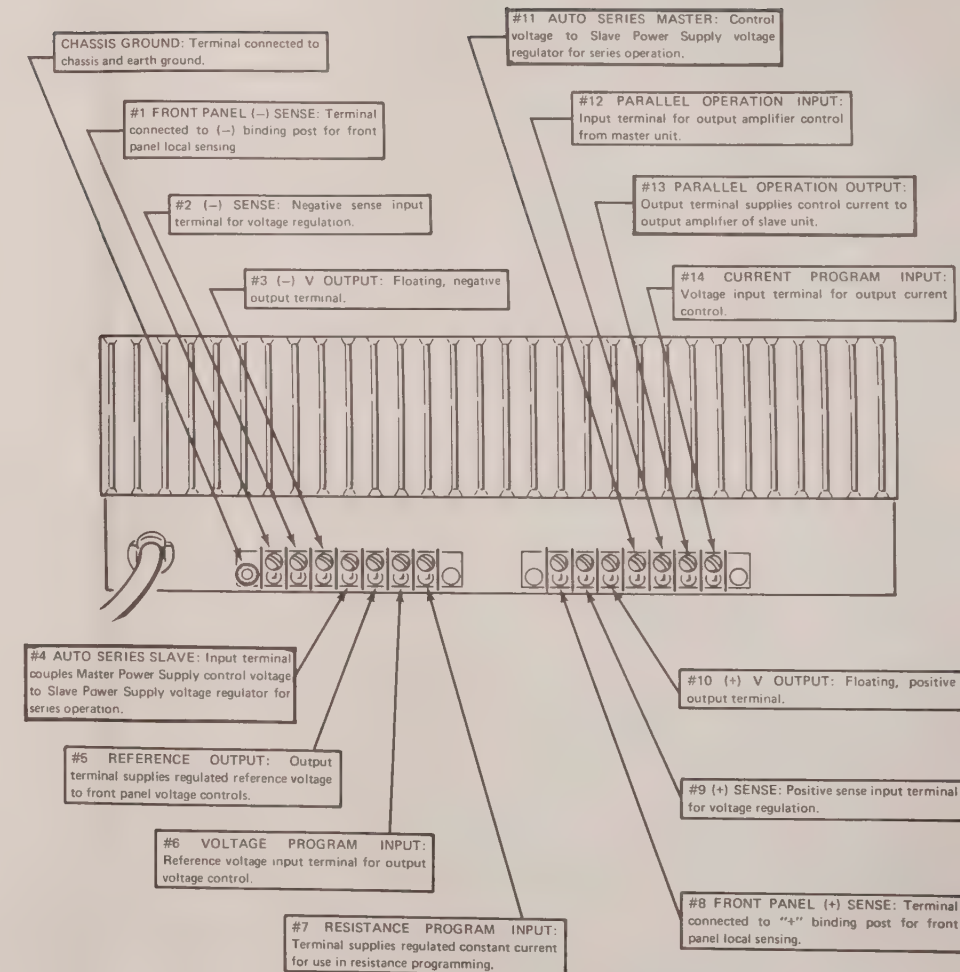


Figure 1-2

WAVEFORMS TEST CHART

WAVE FORM NO.	Integrated Circuits Removed	Integrated Circuits Installed	CAL Jumper Position	RANGING Jumper Position	Oscilloscope Settings (V,T/cm)	Oscilloscope Test Point	Shorting Location	Comment
1	None	—	LO CAL	AUTO	V: 2 V H: 5 ms	Pin 14 of IC312	None	This LINE SYNC waveform verifies operation of +5.0 VDC supply and the LINE SYNC circuitry.
2	None	—	Same	Same	V: 1 V H: 2 μ s	Pin 11 of IC312	None	Verifies Operation of IC312 and associated circuitry.*
3	IC308 IC309 IC311.	—	Same	Same	Same	Pin 12 of IC310	None	Verifies operation of IC310A and associated circuitry.
4	Same	—	Same	Same	V: 1 V H: 20 μ s	Pin 11 of IC301	None	Verifies operation of IC301.
5	Same	—	Same	Same	V: 1 V H: 0.2 ms	Pin 11 of IC303	None	Verifies operation of IC303.
6	Same	—	Same	Same	V: 1 V H: 2 ms	Pin 11 of IC305	None	Verifies operation of IC305. Some jitter may be experienced.
7	Same	—	Same	Same	V: 1 V H: 10 ms	Pin 11 of IC307	None	Verifies operation of IC307.
8	IC308 IC311	IC309	Same	Same	Same	Pin 8 of IC309	None	Verifies operation of IC309.
9	Same	—	Same	HIGH ONLY	Same	Pin 8 of IC310	None	Verifies operation of IC310C.
10	Same	—	Same	AUTO	Same	Pin 6 of IC310	Pins 8 and 9 of IC310	Verifies operation of IC310B.
11	IC302 IC308 IC311	—	Same	Same	V: 2 V H: 10 ms	Collector of Q302	Pins 8 and 9 of IC310	Verifies operation of Q301, Q302, and associated circuitry. Requires operation of +6.2 VDC supply.
12	Same	—	Same	Same	Same	Collector of Q306	Pins 8 and 9 of IC310	Verifies operation of Q304, Q305, Q306, and associated circuitry.

*You may have some difficulty observing this waveform.

WAVE FORM NO.	Integrated Circuits Removed	Integrated Circuits Installed	CAL Jumper Position	RANGING Jumper Position	Oscilloscope Settings (V,T/cm)	Oscilloscope Test Point	Shorting Location	Comment
13	IC311	IC302 IC308	Same	Same	V: 1 V H: 20 ms	Pin 6 of IC308	None	Verifies operation of IC308C.
14	Same	—	Same	Same	V: 2 V H: 20 ms	Pin 3 of IC314	None	Verifies operation of IC313A and IC314A.
15	IC311 IC316	—	Same	Same	Same	Pin 4 of IC314	None	Verifies operation of IC313C and IC314B.
Interchange IC311, which is presently out of the circuit, with IC313. Repeat waveform tests 14 and 15 to verify operation of IC311A and IC311C. Leave them interchanged.								
Install IC313, which is presently out of the circuit, in the IC311 position.								
16	IC316	—	Same	Same	Same	Pin 11 of IC314	Pins 13 and 14 of IC313	Verifies operation of IC311D, IC313B, and IC314D. Remember IC311 is in the IC313 position.
Interchange the integrated circuits in the IC311 and IC313 positions. Repeat waveform test 16 to verify operation of IC311B and IC313D. They will not be interchanged again.								
17	Same	—	HI CAL	HIGH ONLY	V: 1 V H: 20 ms	Pin 3 of IC315	None	Verifies operation of IC315B and IC315C. Also verifies that IC315D is not shorted. Requires HI CAL and REFERENCE (high range) voltages.
18	IC315	IC316	LO CAL	AUTO	Same	Pin 7 of IC316	Pins 1 and 2 of IC315	Verifies basic operation of IC316, IC317, and associated circuitry. May require several seconds to stabilize.
19	None	IC315	Same	Same	V: 50 V H: 10 ms	“BP” on Readout board	None	Verifies presence of HV (high voltage).

DISPLAY TROUBLESHOOTING PROGRAM

The "Waveforms Test Chart" (fold-out from page 22) is used to verify various waveforms in the display circuitry. Each numbered step is a test set-up which should produce the waveform of the same number as shown on the accompanying illustrations. These numbers are also keyed in the Schematic. The waveforms are on the fold-out from Page 47.

Should you complete a test and not obtain the indicated waveform, this indicates that either the indicated IC (IC's) is defective, or there are some problems in its associated circuitry.

NOTE: Each waveform generally requires that all previously indicated waveforms have been verified. Therefore, you must follow the tests in sequence, starting at waveform #1.

To check for the presence of the various waveforms, you will need:

1. A DC-coupled oscilloscope with vertical calibration from 0.5 volts/centimeter to 50 volts/centimeter and a time base (horizontal) calibrated from 2 microseconds/centimeter to 20 milliseconds/centimeter.
2. A high-impedance (10 Megohm suggested), low-capacitance probe.

To prepare the Power Supply for the waveform tests:

1. Position the INPUT jumper wire on the CAL pin (display circuit board).
2. Press in the VOLT switch.
3. Connect the oscilloscope ground (common) to the shield wire at hole BC on the display circuit board.

At each waveform test, perform each of the following steps:

1. Be sure to push the PWR switch to off before:
 - a. Removing an integrated circuit.

- b. Reinstalling an integrated circuit.
- c. Changing the position of a jumper.
- d. Locating a point where a short is to be applied. (Do not apply the short until directed to do so.)

2. Remove or install the indicated integrated circuit (IC).
3. Connect the CAL and/or RANGING jumpers as indicated.
4. Adjust the oscilloscope for the designated time and voltage settings for the waveform to be observed. Adjust the DC vertical position ("zero") level to some convenient point.
5. Push the PWR switch to on.
6. Connect or touch the oscilloscope probe tip to the indicated test point.
7. Refer to the "Comment" column to determine any special information.
8. Short the indicated integrated circuit pins together with a small screwdriver or a short piece of wire as required. Apply the short only as long as necessary. Do not apply the short for more than 1 (one) minute out of every 5 (five) minutes.
9. Adjust the triggering controls of the oscilloscope to obtain the proper presentation.
10. If the proper waveform is obtained, proceed to the next test. If it is not obtained, push the PWR switch to off (out) and verify that the test connections are correct. If they are, refer to the "Comments" portion of the test chart.

NOTE: The arrow on the left edge of each waveform photograph indicates the DC "zero" level to which it is referenced.

CIRCUIT DESCRIPTION

This Power Supply consists of six basic circuits: The power source, the output amplifier current source, the output amplifier, the voltage regulator, the current regulator, and the display circuit. Each circuit will be described in its operation and relationship to the other circuits. Refer to the Schematic Diagram (fold-in), the Block Diagram (fold-out from Page 8), and the display circuit diagrams (fold-out from page 33), as you read the following description.

POWER SOURCE

Transformer T1 has a dual primary winding that can be switch-selected to allow operation from either a 120 VAC or a 240 VAC, 50/60 Hz power source. The secondary windings supply the AC voltages required to power the various circuits.

Power for the output amplifier is supplied by the first winding (green, green-yellow, and green leads) through the rectifier filter. The AC voltage is first rectified by diodes D1 and D2. Then it is filtered by capacitors C2 (and C3), and resistor R2 (and R3), to produce the required output level.

The second transformer winding (blue, blue-yellow, and blue leads) is connected to the output amplifier current source. (This circuit will be described later.)

Diodes D111, D112, D116, and D117 rectify the AC voltage from the third transformer winding (brown, brown-black, and brown leads) to produce a +20 VDC and a -20 VDC source for the +11 VDC and -11 VDC supplies. Capacitor C111 filters the +20 VDC source. Resistors R111 and R112, zener diode D113, and transistor Q102 comprise a constant current source. The voltage drop across D113 is constant, due to its zener action. This forces the voltage across R112 and the base-emitter junction of Q102 to be constant. The

constant voltage across R112 produces a constant current at the emitter of Q102. Therefore, the collector current of Q102 is constant. This constant current source maintains a constant current flow through zener diode D114 to insure a constant bias voltage at the base of pass transistor Q103. Thus, regulated +11 volts is produced at the output of Q103 for use in the current and voltage regulators.

The constant current from the collector of Q102 is also coupled through resistor R113 to zener diode D115, and produces a constant voltage that is used as a reference by the voltage regulator. Control R116 adjusts the reference voltage level to limit the maximum output voltage level. This voltage is also coupled to the base of transistor Q104 as a reference. The +11 volts is passed through resistors R114 and R115 to develop a constant current at the emitter of Q104. The constant current produced at the collector of Q104 is used in the resistance programming mode of operation, for control of voltage regulator. Control R114 sets the current level for a calibrated output.

Capacitor C115 filters the -20 VDC source and resistor R117 supplies current to zener diode D118. This produces a constant voltage reference to the base of pass transistor Q105. Thus, a regulated -11 volts is produced at the output of Q105 for use in the current and voltage regulators.

Transistor Q106 is wired as a negative current source. A constant voltage is developed across zener diode D119 and resistor R118 at the base of Q106. This produces a constant voltage across emitter resistor R119. Thus, the collector becomes a constant current "sink" for the output amplifier

drivers to insure that the output transistors are biased off when the power supply is adjusted for a zero output level.

The three remaining secondary transformer windings are used to power the display circuits, described later.

OUTPUT AMPLIFIER CURRENT SOURCE

This circuit supplies drive current to the output amplifier. Its constant current output is controlled by the current and voltage regulators to maintain the desired power supply output level. The individual control circuits will be described later.

Diodes D101 and D102 rectify the AC voltage from the second secondary transformer winding (blue, blue-yellow,

and blue), while capacitor C101 removes any ripple from the DC voltage produced. The center tap of the transformer winding is connected to the output amplifier collectors, to insure that this current supply is always at a higher DC voltage level than the output amplifier. Zener diode D103, resistor R104, and transistor Q101 form a constant current source which supplies current to the output amplifier.

OUTPUT AMPLIFIER

The output amplifier supplies the output power, and consists of driver transistor Q1 and power transistors Q2, Q3 (Q4). The power transistors are connected in parallel, with emitter resistors to force current sharing. Driver transistor Q1 is connected to the power transistors in a Darlington configuration for increased current gain. Resistors R12 and R14 (and R16), and capacitor C11 provide high frequency stabilization.

Current from the output amplifier current source (Q101) is amplified by Q1 and coupled to the base of the power transistors. This current determines the voltage and max-

imum current passed by the power transistors. As previously mentioned, the output amplifier current source operates at a higher DC voltage level than does the output amplifier. This insures that up to six* power supplies can operate in parallel with complete voltage and current control.

Diode D22 is connected between the +V output and the positive sense to insure that the output level will not exceed the component power limitations in case the sense line should open, or is not connected. Diode D154 serves the same function for the negative sense line.

*Six SP-2701

Four SP-2711

Three SP-2721

Two SP-2731

VOLTAGE REGULATOR

The voltage regulator maintains the output voltage level, and consists of three primary circuits: A differential comparator that compares a sample of the output voltage to a reference voltage, differential amplifier to amplify the error signal from the comparator, and a DC level-shift amplifier to "sink" the current from the output amplifier current source.

Transistors Q110 and Q111 comprise a differential voltage comparator, while transistor Q112, resistor R136, and zener diode D131 form a constant current source for the comparator. Control R135 balances the current flow so that a zero reference voltage will produce a zero output voltage.

A reference voltage is coupled to the base of Q110 through voltage control R21/R22 or the external resistance program terminal. Diodes D121 and D122 provide voltage protection for the comparator. Divider resistors R142 and R143 supply a sample of the output voltage (+V) to the base of Q111. Assuming the base voltages to Q110 and Q111 are equal, the collector current of each transistor is also equal. If the reference voltage is decreased, the collector current of Q110 will decrease and force an equal increase of Q111 collector current. A change in current flow through resistors R133 and R134 will cause a voltage change at the collectors of Q110 and Q111. This voltage is coupled to the bases of the

differential amplifier Q108 and Q109. Diode D123 provides voltage protection for transistors Q108 and Q109.

The collector of Q111 is connected to the base of Q108. A decrease in the collector voltage of Q111 will cause an increase in the base current and, therefore, the collector current of Q108, to produce a higher voltage across resistor R122. This increase in base voltage results in an increase in collector voltage. This voltage is coupled to the DC level-shift amplifier, Q107. Emitter voltage is held constant by the differential operation of transistors Q108 and Q109.

DC level-shift amplifier Q107 operates as a current "sink" for the output amplifier current source. As the collector voltage of Q108 increases, the base current of Q107 increases. This increases the collector current, which "sinks" more current from the output amplifier current source. As current to the output amplifier is reduced, the output voltage level is reduced until there is no longer a voltage difference at the differential comparator.

High frequency stabilization is provided in the voltage regulator through RC networks R121-C121, R126-C126, R128-C128, and R129-C129.

CURRENT REGULATOR

Current limiting is controlled by the current regulator, which contains two basic circuits: an operational amplifier, which compares a reference voltage to the voltage drop across the current sense resistor (R158); and a DC level-shift amplifier to sink current from the output amplifier current source.

Reference diodes D161 and D162 supply a constant negative voltage to the maximum current control, R162, and then to current control R23. This reference voltage is coupled to pin 3 (positive input) of comparator IC101. The output current produces a voltage drop across sense resistor R158 that is coupled to pin 2 (negative input) of comparator IC101. If the voltage at pin 2 is more negative than the voltage at pin 3, the output at pin 6 of the comparator is positive. The output is negative if pin 3 is more negative than pin 2. Diode D151

couples only positive voltage error signals to the DC level-shift amplifier Q113. Resistor R154 and capacitor C152 in the feedback loop control the gain and frequency response in the comparator. Control R152 is adjusted for a zero output with a balanced comparator input. Diodes D152 and D153, and resistors R155 and R156 provide voltage protection at the input of the comparator.

As the output current exceeds the level set by the current control, the comparator generates a positive voltage that is coupled to the base of DC level-shift amplifier Q113. This increases the base current, which in turn increases the collector current and sinks current from the output amplifier current source. A lower current level to the output amplifier will limit the current the output amplifier can supply.

DISPLAY CIRCUIT

The digital display (readout) circuit provides switch-selected monitoring of the output voltage or current. This is accomplished through a patented* dual-slope integrating technique that compensates for temperature and line-voltage variations to maintain display accuracy. Because of the complexity of the circuit, it will first be described in simplified form, and then in detail.

THEORY OF OPERATION

Refer to Figure 2-1, a block diagram of the display circuit, and Figure 2-2, functional waveforms (fold-out from Page 33), as you read this description.

The line sync signal (waveform #1), derived from the line voltage frequency at 50 or 60 Hz, is applied to the start circuit, a $\div 8$ counter. After 8 cycles, the start circuit generates a short (1 μ s) pulse (waveform #2). This "start" pulse resets the display counters to 9000, and resets the control circuit for a measurement cycle. When reset, the control circuit starts the clock (waveform #3) and switches the analog circuit to the "integrate" mode (waveform #4). As the counters count the clock pulses, the integrator output develops a charge voltage on integrating capacitor "C" (waveform #5) at a rate proportional to the negative input voltage [that is, the charge voltage versus time (slope) increases with higher input voltage levels]. Integration continues as the counters count from 9000 to 9999. The next clock pulse "sets" the counters to 0000, which tells the control circuit to switch the analog circuit to the "reference" mode (waveform #6).

While the counters continue to count up from 0000 a positive reference voltage causes the voltage across integrating capacitor "C" to "ramp" back toward zero. The ramp slope is constant, because of the fixed reference voltage. When the detector senses a zero voltage across "C," its output goes low (waveform #7) and signals the control circuit to turn off the clock. The count stored in the counters is proportional to the input voltage. When the control circuit turns off the clock, it also switches the analog circuit to the "auto-zero" mode (waveform #8). This lets the integrator and detector stabilize to prepare for a new measurement cycle.

During the preceding operations, the high voltage power (HV) to the display tubes was low, as represented by the dotted portion of waveform #9, and the display was not lighted. As the high voltage goes more positive, a level is reached where the gas in the tubes ionizes (waveform #10), and the seven-segment digits display the count stored in the counters. Each of the next seven positive portions of the high voltage will relight the display tubes.

If, during the "reference" mode of operation, the count exceeds 1999, the overrange (O/R) output of the counters turns the clock off and triggers the ranging circuit. This increases the reference voltage level by a factor of 10, and shifts the decimal point (DP) position. Thus, on the next measurement cycle, integrating capacitor "C" will discharge 10 times more quickly and the count will be displayed with one decade less resolution.

COUNTING CIRCUIT

NOTE: A logic high signal refers to a voltage level greater than 2.5 volts DC, while a logic low level is less than 1 volt DC.

With each "start" pulse (logic high pulse) from the control circuit, counters IC301, IC303, and IC305 are reset to 0 (A, B, C, D outputs logic low) and IC307 is reset to 9 (A and D outputs logic high; B and C outputs logic low). IC 307 is a $\div 5$ counter: Its B output is used to control the fourth digit "1." The D and C outputs function as part of the control circuit. Output A is not used.

Output C is inverted by IC308C (pin 6 high), and coupled to pin 3 of IC310B and pin 1 of IC310A. The BUSY line from IC311B to pin 2 of IC310A is forced high by the high on the D output of IC307. Pin 12 of IC310A was initially high (BUSY line low) which charged capacitors C308 and C309. With C308 and C309 charged to the logic high threshold of pin 13, and with pin 2 now also high, pin 12 is forced low. This provides a discharge path for C308 and C309 through coil L301 and diode D301. Diode D301 limits the voltage to which C308 and C309 discharge. As C308 and C309 discharge, pin 13 goes low, which forces pin 12 high and allows C308 and

*U.S. Patents 3,051,939 and 3,316,547.

C309 to recharge (from pin 13). This "clock" circuit continues to oscillate as long as pins 1 and 2 of IC310A remain high. Capacitor C310 limits the rise time of the clock signal to minimize noise radiation.

The pulses from the clock drive the input (A IN) of decade counter IC301 at approximately a 500 kHz rate. Each complete pulse (low-high, high-low transition) advances the counter one count. This count is translated into BCD (binary coded decimal) information and coupled to decoder driver IC302. Here the BCD information is translated into 7-segment information to drive the seven segments of digit 1, of display tube V302. The driven segments of the display tube do not light until the +185 volts peak signal goes positive at the anode (AN) of the tube.

The D output of IC301 pulses the input (A IN) of IC303 each time IC301 advanced from a 9 to a 0. This causes IC303 to accumulate the "tens" count. Its BCD output is translated by IC304 and drives digit 2 of display tube V302. In like manner, IC305 accumulates the "hundreds" of count. The D output of IC305 also pulses the BD input of IC307. This causes IC307 to accumulate the "thousands" count.

As previously mentioned, the D output of IC307 forces the BUSY line high through gate IC311B. This (and IC313A and B) also sets the control circuit to the "integrate" mode. After exactly 1000 counts have accumulated, IC307 is advanced from its 9 condition to a 0 condition (all outputs low). A low from D (along with a signal from the Detector circuit) sets the control circuit to the "reference" mode. While in the "reference" mode, the integrator is forced to ramp back toward zero, and the clock pulses accumulate in the counters (starting from a 0000 count).

When the integrator reaches zero, the BUSY line is forced low, and the clock is stopped. The counters continue to hold their accumulated count. As the HV line goes sufficiently positive, current flows from each AN input to the decoder drivers, and the selected display segments light. Resistors R315, R316, and R317 supply a control current to their respective decoder drivers to regulate the current flow through the display segment drivers. When the fourth digit is turned on, output B of IC307 holds the base of Q309 high at a fixed level. This regulates the current through display segment driver Q309 since any current increase would increase the voltage across R314 and tend to turn Q309 off.

If the accumulated count exceeded 1999 before the integrator reached a zero level, output C of IC307 would go high (2000 count). The high from C is inverted by IC308C to turn the clock off. It also switches gate circuit IC310B and C to force the Ranging circuit to select the high reference voltage and change the decimal point position.

The decimal point (DP) lines from display digits 2, 3, and 4 are connected through the VOLT (SW5) and AMP (SW4) front panel switches to transistors Q307 and Q303. Q307 is activated on the low reference voltage range, and connected to DP of digit 3 for Volts display, or DP of digit 4 for Amps display. On the high reference voltage range, Q303 is activated and connected to DP of digit 2 for Volts display, or DP of digit 3 for Amps display.

Each display tube (V301 and V302) has two KA (keep alive) electrodes. Each pair of electrodes is connected through a resistor, R312 or R313, to -185 volts. These electrodes provide ionization to speed the initial turn on of the display tube.

CONTROL CIRCUIT

To better understand the control circuit, many of the signal paths are tagged with signal logic levels (H for high, and L for low). In the Schematic, the "integrate" mode is the top letter; the "reference" mode is the center letter; and the "auto-zero" mode is the bottom letter. As you may know, all inputs to a NAND gate, such as IC313C, must be high (H) before the output will go low (L). While for a NOR gate, such as IC314B, if either input is high (H), the output will go low (L). In either case, if an input is not connected, it is always considered to be high (H).

The sequence of operation begins, as before, with the eighth line sync pulse to counter IC312. When this pulse is counted, the D output (start pulse) of IC312 goes high, and resets counters IC301, IC303, IC305, and IC307. After about 1 μ s, the feedback network of R346 and C314 forces the RO (zero reset), pin 2 of IC312, to go high and reset IC312 to zero (D output goes low). As soon as the start pulse returns to a low level the counters begin counting the clock pulses.

To better understand the control circuit, each operational mode will be described in relation to the logic level of each control gate.

Integrate Mode

1. The detector output (pin 7 of IC316) is forced high by integrator IC317 at the start of each measurement cycle due to the previous "auto-zero" mode (to be described later).
2. The D output of IC307 is high. This forces the output of IC313A low and causes the output of IC313C to go high. This inhibits IC314B through pin 5 (no "reference" mode allowed).
3. The low at the output of IC313A also forces the output of IC311B to go high. This is the BUSY signal mentioned in the counter circuit description.
4. With the BUSY signal high, IC314D is inhibited through pins 12 and 13 (no "auto-zero" mode allowed.)
5. However, the low at the output of IC313A enables IC314A through pins 1 and 2 ("integrate" mode is allowed).
6. The high signal from the Detector, after inversion through IC313B, is reinverted by IC313D and coupled to pin 9 of IC311C. The high BUSY signal is coupled to pin 10 of IC311C. This forces the output of IC311C low, and inhibits the output of IC309 from going low while the counters continue to count the clock pulses.

During the "Integrate" mode, the integrator charges the integrating capacitor (C306). After 1000 counts have accumulated in the counters, a new control cycle is started.

Reference Mode

1. As the counters reach 0000, the D output of IC307 goes low.
2. The low D level forces the output of IC313A high and inhibits IC314A (no "integrate" mode allowed).
3. The Detector output remains high (it goes low at the end of this mode).
4. With the output of IC313A high, and the BUSY line held high by the low from IC311C, the output of IC313C is forced low. This low, with the low from IC313B, enables IC314B through pins 5 and 6 ("reference" mode is allowed).

5. The BUSY line is high, so IC314D is still inhibited through pins 12 and 13 (no "auto-zero" mode allowed).
6. The low at the output of IC311C continues to inhibit IC309 from going low while the counters continue to count the clock pulses.

During the "reference" mode, the integrator discharges the previously stored charge on the integrating capacitor while the counters accumulate counts. This continues until the charge on the integrating capacitor reaches zero; then a new control cycle is started.

Auto-Zero Mode

1. As the integrator charge (voltage across C306) reaches zero (actually slightly positive), the Detector output goes low, the output of IC313B goes high, the output of IC313D goes low, and the output of IC311C goes high. This high at pin 4 of IC311B, along with the high on pin 5 from IC313A, forces the BUSY line low inhibiting the clock circuit at pin 2 of IC310A.
2. The low BUSY line also forces the output of IC313C high. This inhibits IC314B through pin 5 (no "reference" mode allowed).
3. The output of IC313A is still high, inhibiting IC314A through pins 1 and 2 (no "integrate" mode allowed).
4. The low BUSY line enables IC314D through pins 12 and 13 ("auto-zero" mode is allowed).

This completes the basic measurement control cycle, until the next start pulse is generated. Two other control functions can occur and disrupt the normal cycle. These are an overrange (O/R) condition, and a down-range condition.

Automatic Ranging Control

If, during the "reference" control mode the count exceeds 1999, an O/R (high) pulse is generated by the C output of IC307. This is inverted by IC308C and turns off the clock circuit. The O/R signal also triggers the ranging circuit through IC310B, which forces the reference circuit to select the high range reference voltage. Operation in the high range will continue as long as the count for each measurement cycle is 180 or higher. A count of 179 or lower will force the down-range detector (IC308A, B, D, E, F, and IC309) output low. To logically force the output of IC309 low:

1. The control circuit must be in the "auto-zero" mode IC309 pin 11 high.

2. There is no "1" in Digit 4, IC308F pin 13 low, forcing IC309 pin 1 high.
3. There is no "2" in Digit 3 (IC308A pin 1 low, forcing IC309 pin 4 high).
4. There is no "4" in Digit 3 (IC308B pin 3 low, forcing IC309 pin 5 high).
5. There is no "8" in Digit 3 (IC308E pin 11 low, forcing IC309 pin 2 high).
6. There is no "8" in Digit 2 (IC308D pin 9 low, forcing IC309 pin 3 high).
7. The first line sync cycle ends (IC309 pin 6 high).

Under these conditions, the ranging circuit is toggled (IC310B and C outputs reverse) and the reference voltage is switched to the low range.

ANALOG CIRCUIT

The analog circuit consists of a dual-slope voltage integrator that compares the input voltage to a reference voltage that is determined by the ranging circuit. The following description tells how this circuit functions with the counting and control circuits.

NOTE: Various functions are controlled by FET (field-effect transistor) switches housed in IC315. A logic level high (H) to an FET switch input will turn the switch on (contacts closed) and a logic, level low (L) will turn the switch off (contacts open). In the following description, any reference to an FET switch will identify the switch and its "state" (on or off).

Dual-Slope Circuit

NOTE: Although the "auto-zero" mode is the last function selected by the control circuit, it is described first since the "auto-zero" mode prepares the analog circuit for operation.

After each measurement cycle, the "auto-zero" mode is selected by the control circuit. During this time, FET switches IC315B and IC315C are turned off, and IC315A and IC315D are turned on. Through FET switch IC315D, the negative lead of capacitor C304 is tied to ground, representing a zero input voltage. The output of detector IC316 is connected to the positive lead of C304 and the input of integrator IC317 through IC315A.

Both integrator IC317 and detector IC316 are operational amplifiers, and therefore have a very small internal offset voltage across their inputs. This offset is amplified and can cause a large error in the measurement.

When the analog circuit is switched to the auto-zero mode, the output of IC316 is coupled back to the input of IC317 through IC315A. This provides a path to null out the effect of the offset voltages. For instance, if the offset voltage in IC317 causes its output (pin 6) to drift in a negative direction, a level will be reached where the output of IC317 will exceed the input offset voltage of IC316. This will force the output of IC316 high ("pulled" toward +5 volts by resistor R307). As the output of IC316 swings toward +5 volts, capacitor C304 begins to charge positively through resistor R308 and FET switch IC315A. When the charge on C304 exceeds the input offset voltage of IC317, the output of IC317 will begin to drift in a positive direction. As the required input level of IC316 is reached, its output will switch low (internally "pulled" to ground). Capacitor C304 can now discharge through resistors R308 to ground and R309 to -7.5 volts. When capacitor C304 has discharged to a low enough level, the output of IC317 will again begin to drift low. This fluctuation of charge on C304 will reach a relatively stable level (positive or negative) where the effect of the offset voltages of IC316 and IC317 are "nulled" out. Therefore, the integrator and detector "see" an effective zero input level during this portion of each measurement cycle. The -7.5 volt source through R309 insures that C304 can charge sufficiently negative; while capacitor C307 increases the voltage time constant at pin 7 of IC316 during positive level shifts.

The voltage input to the display circuit is connected from switch SW4 through a coaxial cable. The outer (shield) lead of the coaxial cable is connected to the "zero" network of resistors R302, R303, and Zero Adj control R304. The voltage at the wiper of control R304 is divided by R302 and R303 to provide a small variable (positive or negative) voltage which is coupled through either R301 or R27, to eliminate any residual offset voltage near zero. During voltage measurements, R24 and R301 divide the Power Supply output voltage by 100 to provide a full-scale sensitivity of 20 volts on the low range and 200 volts on the high range. For current measurements, the Power Supply output current is sensed by R27 to provide a full-scale sensitivity of 2 amperes on the low range and 20 amperes on the high range.

During the "auto-zero" mode, the input voltage is allowed to charge capacitors C301 and C302. When the control circuit switches the analog circuit to the "integrate" mode, FET switches IC315A and D open, and IC315B closes.

As IC315B closes, the negative voltage on capacitors C301 and C302 is coupled through C304 along with the positive or negative charge on C304 (from the "auto-zero" mode) to the input of integrator IC317. This forces the output of IC317 negative. Since the charge on capacitor C304 can only be discharged by the small input current of IC317, its charge is maintained throughout the measurement cycle.

The gain of IC317 is sufficient to insure that enough current will flow through capacitor C306 (the integrating capacitor) to make the voltage across R306 equal to the input voltage. With a constant voltage at the input, the voltage to C306 must increase at a constant rate and produce a balancing voltage on R306. The peak voltage across C306 after 1000 counts is proportional to the input voltage. This completes the "integrate" mode. The analog circuit is then switched to the "reference" mode; FET switch IC315B opens and IC315C closes.

As previously mentioned, at the beginning of the "reference" mode, the counters contain a count of 0000 and continue to count-up. The positive voltage at the wiper of LO CAL control R331 is coupled to the negative (-) lead of capacitor C304. The input (pin 3) of IC317 goes positive, forcing the output positive so that the voltage equal to the reference voltage is now generated across R306. However, the overall voltage across C306 is still negative, so that the output of IC316 is held high. With the constant reversed current flow, C306 begins to discharge toward zero at a linear rate. The discharge continues while the clock pulses accumulate in the counters until the voltage across C306 reaches zero (the previously stored offset voltage of IC316). When this occurs, the output of IC316 goes low, the clock is disabled, and the analog circuit is again switched to the "auto-zero" mode. The count stored in the counters now represents the input voltage.

Ranging and Reference Circuit

When power is applied to the Power Supply, the 5-volt supply increases from zero volts to the regulated 5-volt level. This voltage change is coupled through capacitor C313 to resistors R343, R344, and the base of Q308. (Diode D302 is reverse-biased by this change in voltage and does not conduct.) Current flow through R343 turns Q308 on; its collector pulls pin 10 of IC310C low and forces its output and pin 5 of IC310B high. Pin 3 of IC310B is forced high by IC307, through IC308C, and pin 4 of IC310B is high because of its open circuit. Therefore, the output of IC310B is forced low and holds pin 11 of IC310C low. As soon as C313 is charged, Q308 turns off and pin 10 of IC310C is allowed to go high (open circuit). This sequence simulates a "down-range" signal and insures that the first measurement cycle will always start in the low (reference voltage) range. When the Power Supply is turned off, the 5-volt supply goes to zero, D302 is no longer reverse-biased, and C313 is allowed to discharge through D302.

A logic low from IC310B is coupled to the base of transistors Q301 and Q304. This turns off both transistors. With Q301 off, Q302 and Q303 are held off. Therefore, the right decimal point (DP) drive circuit is open (high-range DP disabled).

However, with Q304 turned off, current is allowed to flow through resistor R335 and turn on Q305. The collector current of Q305 flows through the emitter-base junction of Q306 and R338. This drives Q306 on into "saturation." The 6.2-volt supply is then applied to the junction of R339, R341, and the base of Q307. With a fixed base voltage, the voltage across emitter resistor R342 is constant which maintains a constant current through the left DP drive circuit (digit 3 for VOLT, and digit 4 for AMP). In addition, the 6.2-volt supply at R341 is divided between it and R331, R332, and R333 network. The wiper of LO CAL control R331 is nominally set at 0.10 volts. This is the low-range reference voltage to pin 8 of FET switch IC315C during the "reference" mode measurement cycle.

If during a measurement cycle, the count exceeds 1999, the "over-range" line to pin 3 of IC310B will go low. This forces the output (pin 6) high and pin 11 of IC310C high, the output, pin 8, is forced low. This low coupled to pin 5 of IC310B insures that the output of IC310B remains high until a "down-range" signal from the control circuit is generated (count of 179 or lower).

The logic high from IC310B is coupled to the base of transistor Q301 and Q304. This turns both transistors on. With Q304 on, Q305 is held off. Since no current can flow through the emitter-base junction of Q306, Q306 is held off and Q307 cannot provide a current path for the left DP drive circuit.

With Q301 turned on, current can flow through the emitter-base junction of Q302 (and R323), and drive Q302 into "saturation." The 6.2-volt supply is then applied to the junction of R325, R326, and the base of Q303. Q303 turns on and, as in the low range, a current path is provided for the right DP drive circuit (digit 2 for VOLT and digit 3 for AMP). In addition, the 6.2-volt supply is divided between R325, R326, R327, and R331, R332, R333. This increases the voltage at the wiper of LO CAL control R331 (with adjustment of HI CAL control R327) to 1.00 volts. This is the high-range reference voltage to pin 8 of FET switch IC315C during the "reference" mode measurement cycle.

In situations where it is desired, the RANGING jumper wire can be connected to the HIGH ONLY pin. This ties pin 4 of IC310B low (to ground) and insures that the output of IC310B remains high for all measurements.

POWER SUPPLIES

The power supplies convert the three secondary transformer voltages into the various voltage levels required by the display circuits. The following descriptions tell how these circuits function.

185 V pk and –185 VDC Supplies

The AC voltage from e1, (e1, e2, and e3 are AC voltage from the secondary windings of transformer T1) is rectified by diode D203, on its positive voltage swing to produce a 185-volt peak supply to light the display. It is also rectified by diode D204 and filtered by capacitor C201 to produce the –185-volt DC supply needed to light the KA (keep alive) electrodes of tubes V301 and V302.

Line Sync

The AC voltage from e2 is coupled through resistor R201 to diodes D201 and D202, and resistor R202. During the positive voltage swing, D201 conducts when the level exceeds approximately 5.2 volts to limit the positive level of the line sync signal. Diode D202 is reverse biased during this period. However, on the negative voltage swing, D201 is reverse biased and D202 conducts to limit the negative level to approximately –0.2 volts. Resistor R202 ensures that the line sync signal is held low when e2 is near zero. Thus, the line sync approximates a square wave to minimize any noise that might cause false counts in the count circuit.

+7.5 VDC and +6.2 VDC Supplies

The AC voltage from e2 is also rectified by diode D205 during its positive swing and filtered by capacitor C203. This DC voltage is coupled through resistor R203 to zener diode D216 and the collector of Q206. Zener diode D216 reduces the level to 15 volts. Divider resistors R205 and R206 bias transistor Q206, to produce the regulated +7.5-volt supply. Capacitor C204 provides additional filtering.

Zener diode D217 is biased by the 15 volts through R204 to provide an ultra-stable +6.2-volts for the reference circuit. Capacitor C205 provides additional filtering.

–7.5 VDC and –2.2 VDC Supplies

The AC voltage from e2 is also rectified by diode D206 during its negative swing and filtered by capacitor C207. This DC voltage is coupled to the constant current circuit of transistors Q204 and Q205. Current flow through resistor

R216, the emitter-base junction of Q204, and resistors R217 and R218 turn Q204 on. Transistor Q205 monitors the voltage across R216. As the current flow through R216 increases, the base-emitter junction of Q205 becomes more forward biased. Q205 then conducts more, and pulls the voltage at R217 and R218 more negative, which tends to turn Q204 off. Thus, the feedback operation tends to hold the current flow through Q204 constant. Capacitor C208 prevents oscillation in the circuit.

Zener diode D219 and resistors R221, R222, and R223 were installed as a complete “matched” set during the assembly of the Power Supply. The major portion of the controlled current from Q204 flows through D219 which sets a voltage reference of –7.5-volts. This same current was applied to these four components during the manufacture of this “matched” set and the voltages at the LO CAL and HI CAL points were accurately measured. Thus, high-accuracy, built-in, calibration voltages are provided. The –7.5-volt supply also produced by D219 is filtered by capacitor C211. Divider resistors R224 and R225 reduce the –7.5-volt level to produce the –2.2-volt supply. Capacitor C212 provides additional filtering.

+5.0 VDC Supply

The AC voltage from e3 is full-wave rectified by diodes D211, D212, D213, and D214, and filtered by capacitor C202. This voltage is coupled through transistor Q201 and resistor R212 to zener diode D218. Resistor R211 supplies bias current from capacitor C203 to turn Q201 on. If the voltage at D218 exceeds 5 volts, the voltage at the junction of resistors R214 and R215 will exceed 0.7 volts (there is a 4.3 volt drop across D218). As the voltage at R215 exceeds 0.7 volts, transistor Q203 turns on and diverts base current from Q201. This tends to turn Q201 off. Should the output drop below +5.0-volts, the voltage to Q203 will decrease and turn Q203 off. Resistors R212, R213, and transistor Q202 form a current-limiting circuit. Resistor R212 monitors the current from Q201. Should the voltage across it exceed 0.7 volts, Q202 will turn on and divert base current from Q201, in spite of any action by Q203. Capacitors C206, C311, and C312 filter the +5.0-volt supply.

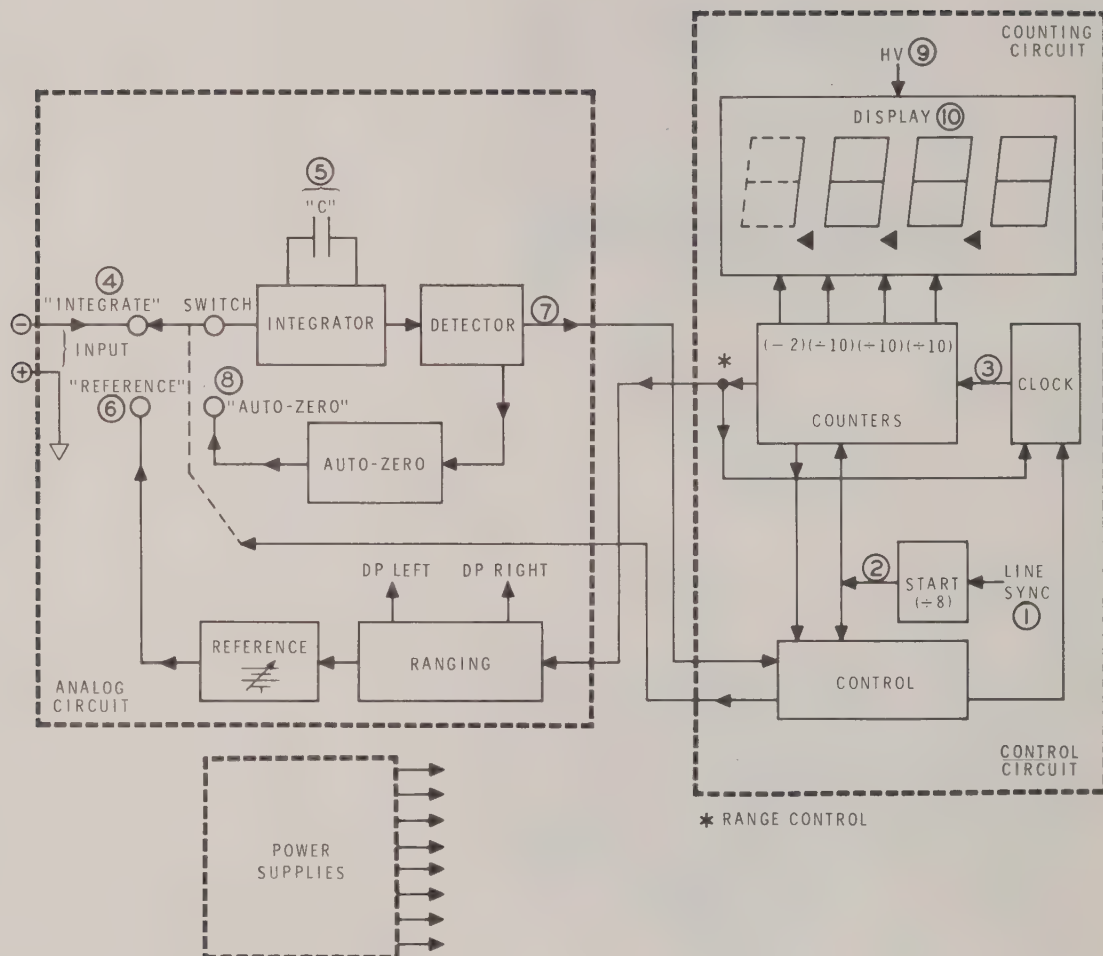


Figure 2-1

CALIBRATION

You can calibrate this Power Supply by either of two methods. The first, which begins below, uses "built-in" standards. The second method (Page 37) requires a precision voltage source that will produce -190 millivolts and -1.90 volts with an accuracy of $\pm 0.05\%$.

After a period of use (three months, for example) you may want to touch-up the calibration to remove any "burn-in" drift.

Refer to Figures 3-1, 3-2, 3-3, and 3-4 (fold-out from Page 34) for the location of the various controls, switches, and test points. If you do not get the proper response in any of these steps, refer to the "In Case of Difficulty" section (Page 17) or to the inside rear cover of this Manual for information on technical assistance.

Preset the front panel controls and switches as follows:

PWR switch — Off (out).

VOLT switch — On (in).

AMP switch — Off (out).

DC ON/STANDBY switch — STANDBY (down).

CURRENT control — Fully counterclockwise.

VOLTAGE controls:

COARSE — Fully counterclockwise.

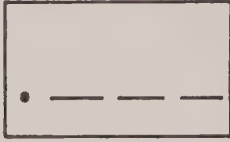
FINE — Fully counterclockwise.

NOTE: If you have a precision voltage source, disregard the following steps and proceed to "Display Circuit Calibration with Precision References" on Page 37. Otherwise, perform the following steps. Use a small-bladed screwdriver (preferably $\frac{1}{8}$ " wide) to make the adjustments.

DISPLAY CIRCUIT CALIBRATION WITH BUILT-IN STANDARDS

1. Check the two rear-panel barrier strips to insure that the jumpers are installed for "Normal" operation. There should be jumpers between terminals 1 and 2, 5 and 6, 8 and 9, and 12 and 13. DO NOT attempt to calibrate the Power Supply in a "program" mode.
2. Insert the line cord plug into the proper AC outlet and press the PWR switch on (in). The display should show a decimal point and three numbers (such as 0.45).
3. Allow the Power Supply 30 minutes to warm up before you begin calibration.
4. Remove the screws that secure the top and left side covers and remove the covers.
5. Turn the COARSE and FINE VOLTAGE controls fully clockwise. The display count should increase.
6. Return the COARSE and FINE VOLTAGE controls to their fully counterclockwise positions. The display should return to its original reading.
7. Press the AMP switch in. The display should read between .000 and .010.

8. Allow the reading to stabilize and record the number that lights most often in the following box.



9. Push the PWR switch off (out).
10. Refer to Figure 3-2 and move the INPUT jumper wire from NORMAL to CAL.
11. Press the PWR switch on (in) and press the VOLT switch in. The display should show a number between 15.00 and 19.00.
12. Refer to the LOW CAL number written on the calibration label, and add .03 to the number. (Example: If the number was 18.18, the result of the addition would be $18.18 + .03 = 18.21$). Now subtract the number you recorded in step 8 from the number you determined in this step. Disregard the decimal point placement in the three digit number (that is, if the number was .007, the result of subtraction would be $18.21 - 7 = 18.14$). Write the final number in the following box.



13. Refer to Figure 3-2 and adjust the LO CAL control (R331) so that the display reads the same as the number in the box from step 12. You must be within one digit of the number. The display may change up and down a digit, but it should show the correct number most of the time.
14. Press the PWR switch off (out).

15. Refer to Figure 3-3 and move the CAL jumper wire on the power supply circuit board from LO to HI.

16. Press the PWR switch on (in). The display should show a reading between 150.0 and 190.0

17. Refer to the HI CAL number written on the calibration table. Then refer to Figure 3-2 and adjust HI CAL control R327, until the display reads the same as the HI CAL number plus or minus one digit.

18. Press the PWR switch off (out).

19. Refer to Figure 3-2 and WITH GREAT CARE, move the INPUT jumper wire from CAL to NORMAL. Be careful not to touch the HI CAL or LO CAL controls or the display circuit board. This may affect the calibration.

20. Refer to Figure 3-3 and move the CAL jumper wire from HI to LO.

21. Press the PWR switch on (in) and press the AMP switch in. The display should show the number from step 8, within one or two digits.

22. Refer to Figure 3-2 and carefully adjust the ZERO ADJ control (R304) so that the display reads .000. It is very important that the display read .000, but it must also shift to .001 occasionally. This insures that you have not adjusted the circuit zero "below" zero. NOTE: Be careful not to touch the HI CAL or LO CAL controls.

This completes the calibration of the display circuits with the "built-in" standards. Proceed to "Control Circuit Calibration" on Page 38.

DISPLAY CIRCUIT CALIBRATION WITH PRECISION REFERENCES

1. Check the two rear-panel barrier strips to insure that the jumpers are installed for "Normal" operation. There should be jumpers between terminals 1 and 2, 5 and 6, 8 and 9, and 12 and 13. DO NOT attempt to calibrate the Power Supply in a "program" mode.
 2. Insert the line cord plug into the proper outlet and press the PWR switch on (in). The display should show a decimal point and three numbers (such as 0.45).
 3. Allow the Power Supply 30 minutes to warm up before you begin calibration.
 4. Remove the screws that secure the top and left side covers and remove the covers.
 5. Turn the COARSE and FINE VOLTAGE controls fully clockwise. The display count should increase.
 6. Return the COARSE and FINE VOLTAGE controls to their fully counterclockwise positions. The display should return to its original reading.
 7. Press the AMP switch in. The display should read between .000 and .010.
 8. Refer to Figure 3-2, and carefully adjust the ZERO ADJ control (R304) so the display reads .000. It is very important that the display read .000, but it must also shift to .001 occasionally. This insures that you have not adjusted the circuit zero "below" zero.
 9. Press the PWR switch off (out).
 10. Refer to Figure 3-2 and disconnect the INPUT jumper wire. Make sure the connector on the end of the wire does not touch anything.
 11. Adjust the precision reference source for -190.0 millivolts, and connect it to the Power Supply: Common lead to the shield wire at hole BC on the display circuit board (see Figure 3-2) and source lead to the connector on the free end of the INPUT jumper wire.
 12. Press the PWR switch on (in) and the VOLT switch in. The display should read between 15.00 and 19.00.
 13. Refer to Figure 3-2 and adjust the LO CAL control (R331) so the display reads 19.00. The display may change up and down a digit, but it should show the correct number most of the time.
 14. Increase the reference to -1.900 volts. The display should read between 150.0 and 190.0.
 15. Refer to Figure 3-2 and adjust the HI CAL control (R327) so the display reads 190.0. The display may change up and down a digit, but it should show the correct number most of the time.
 16. Press the PWR switch off (out).
 17. Disconnect the precision reference source.
 18. Refer to Figure 3-2 and, WITH GREAT CARE, connect the INPUT jumper wire to the NORMAL pin. Be careful not to touch the HI CAL or LO CAL controls, on the display circuit board, or calibration may be affected.
 19. Press the PWR switch on (in), and the AMP switch in. The display should read between .000 and .002.
 20. Refer to Figure 3-2, and carefully readjust the ZERO ADJ control (R304) so that the display reads .000. It is very important that the display read .000, but it must also shift to .001 occasionally. This insures that you have not adjusted the circuit zero "below" zero. NOTE: Be careful not to touch the HI CAL or LO CAL controls.
- This completes the display circuit calibration with precision reference sources. Proceed with "Control Circuit Calibration."

CONTROL CIRCUIT CALIBRATION

NOTE: The following calibration uses the calibrated display circuit. Complete the calibration of the display circuit before you proceed.

1. Remove the screws from the right side panel, and remove the panel.
2. Press the VOLT switch in.
3. Switch the DC ON/STANDBY switch to DC ON.
4. Refer to Figure 3-4 and carefully short terminal strip CE lugs 1 to 3 on switch SW3 with a jumper wire, or use the blade of a screwdriver to short between lugs 2 and 3.
5. Refer to Figure 3-1 and adjust ZERO VOLTAGE control R135 until the display reads between 0.50 and 0.80.
6. Remove the short from the terminal strip. The display should now read 0.00 (it may occasionally shift to 0.01).
7. Turn the COARSE and FINE VOLTAGE controls fully clockwise. NOTE: The display may "auto-range," depending on output rating.
8. Refer to Figure 3-1 and adjust MAXIMUM VOLTAGE control R116 for a display between 1 and 2% over the output rating.
9. Press the AMP switch in.
10. Short the red (+) binding post to the black (-) binding post.

11. Refer to Figure 3-1 and adjust ZERO CURRENT control R152 for a display between .008 and .010 (.030 and .050 for SP-2731).
12. Turn the CURRENT control fully clockwise. The display should show a slightly higher number.

CAUTION: In the next step, you will adjust the control that limits the maximum output current of this Power Supply. Since the output is presently short-circuited, make this adjustment very carefully. DO NOT adjust the current higher than specified; the Power Supply may be damaged or its performance degraded.

NOTE: The display may "auto-range" during this adjustment, depending on the output rating. Do not let the sudden readout shift alarm you and cause you to accidentally exceed the specified maximum current level.

13. Refer to Figure 3-1 and carefully adjust the MAXIMUM CURRENT control (R162) clockwise for a display between 1 and 5% over the output rating. Carefully remove the screwdriver from the control.
14. Switch the DC ON/STANDBY switch to STANDBY.
15. Remove the short from across the output binding posts.

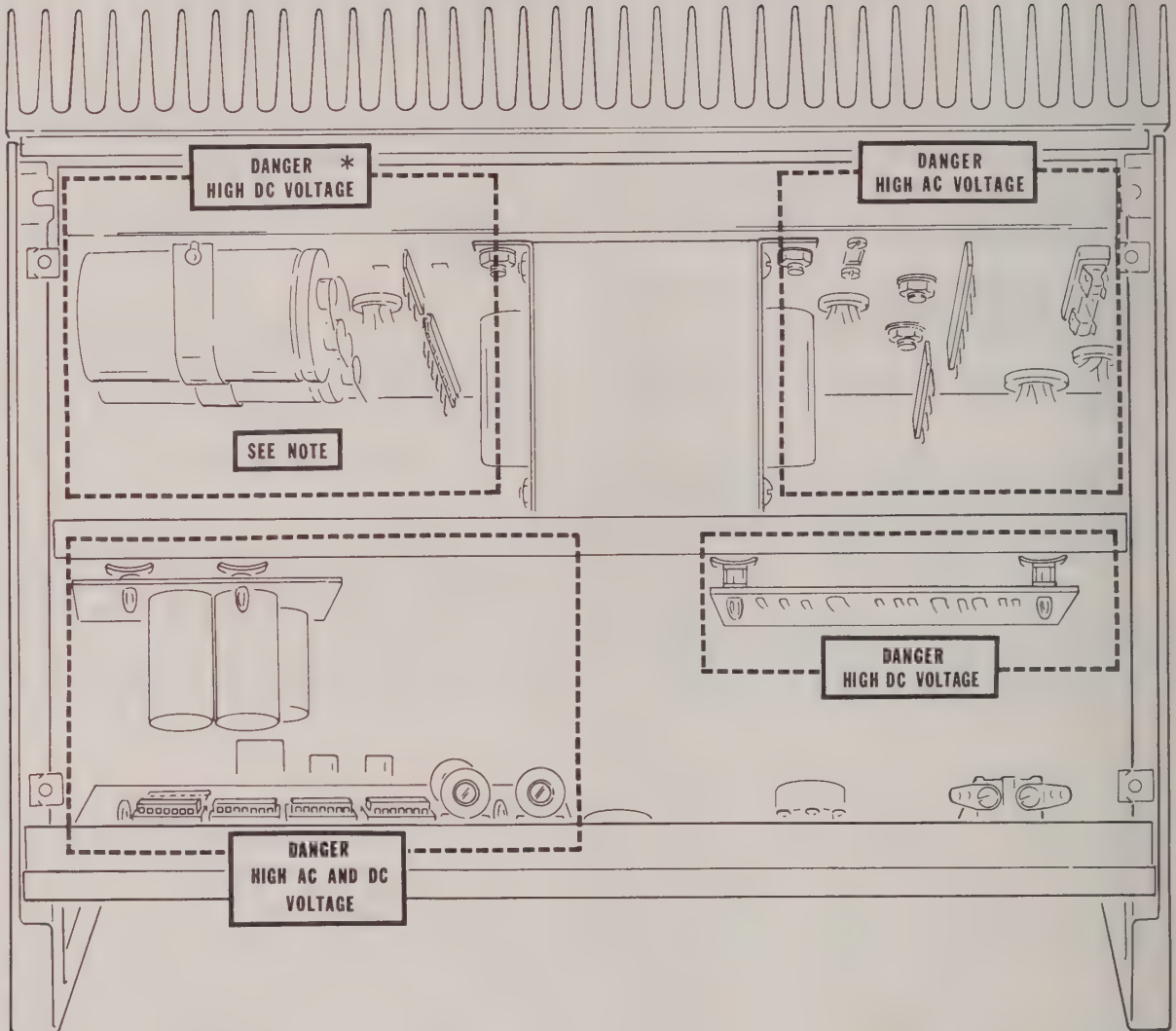
NOTE: The following steps are used to "double-check" your adjustments. If any of the specified displays are incorrect, readjust the control as directed.

16. Turn the COARSE and FINE VOLTAGE controls, and the CURRENT control, fully counterclockwise. The display should read .000, and occasionally .001. If not, refer to Figure 3-2 and carefully readjust ZERO ADJ control R304.

17. Press the VOLT switch in. The display should read 0.00. If not, refer to Figure 3-4 and short terminal strip CE lugs 1 and 3 together. Then refer to Figure 3-1 and readjust ZERO VOLTAGE control R135 for a display between 0.50 and 0.80. Remove the short.
18. Turn the COARSE and FINE VOLTAGE controls fully clockwise. The display should read between 1 and 2 % over the output rating. If not, refer to Figure 3-1 and readjust MAXIMUM VOLTAGE control R-116.
19. Press the AMP switch in. After a few seconds, the display should read between .002 and .004.
20. Short the red (+) binding post to the black (–) binding post.
21. Switch the DC ON/STANDBY switch to DC ON. The display should read between .008 and .010 (.030 and .050 for SP-2731). If not, refer to Figure 3-1 and readjust the ZERO CURRENT control R152.
22. Turn the CURRENT control fully clockwise. The display should read between 1 and 5% over the output rating. If not, refer to Figure 3-1 and very carefully readjust MAXIMUM CURRENT control R162.
23. Switch the DC ON/STANDBY switch to STANDBY.
24. Remove the short from across the output binding posts.
25. Turn the COARSE and FINE VOLTAGE controls, and the CURRENT control fully counterclockwise.
26. Press the PWR switch off (out) and disconnect the line cord plug.
27. Reinstall the top and side panels.

NOTE: If you plan on using your Power Supply in the resistance programming mode, perform the steps in "Example #4" on Page 13 of this Manual.

NOTE: If you wish to hold your Power Supply in the high display range only (because you will be operating near the range-shift point), move the RANGING jumper wire from AUTO to the HI ONLY pin on the display circuit board. Refer to the "Operation" and "Specifications" sections for a complete description of the high display range.



* NOTE: PHYSICAL LAYOUT OF THIS AREA WILL DIFFER BETWEEN UNITS.

Figure 4-1

APPENDIX

This section includes a Parts List of all components necessary for instrument maintenance, Circuit Board X-Ray Views, and system Schematics.

PARTS LIST

Component values and circuit component numbers refer to the Schematics, X-Ray Views, and any related figures. Where there is a component variation between models, it is noted in the description.

Chassis Mounted Components

CIRCUIT Component No.	PART No.	DESCRIPTION	CIRCUIT Component No.	PART No.	DESCRIPTION
RESISTORS			Resistors (cont'd.)		
R1	1-40-2	68 Ω , 10 %, 2-watt	R-11	1-54	15 Ω , 5%, 1/2-watt
	1-1-2	2700 Ω , 10%, 2-watt	R12	1-1	47 Ω , 10%, 1/2-watt
	1-12-2	(SP-2701 and SP-2711)		3-1-2	0.82 Ω , 5%, 2-watt
R2		470 Ω , 10%, 2-watt		3-2-2	(SP-2701)
		(SP-2721)	R13	3-2-2	0.33 Ω , 5%, 2-watt
	3-41-5	140 Ω , 10%, 5-watt		3-14-2	(SP-2711)
		(SP-2731)		3-12-5	0.15 Ω , 5%, 2-watt
R3	1-1-2	2700 Ω , 10%, 2-watt			(SP-2721)
		(SP-2701 and SP-2711)	R-14	1-1	0.09 Ω , 5%, 5-watt
		NOT USED (SP-2721		3-1-2	(SP-2731)
		and SP-2731)		3-1-2	47 Ω , 10%, 1/2-watt
R4	NOT USED			3-2-2	0.82 Ω , 5%, 2-watt
R5	NOT USED			3-2-2	(SP-2701)
R6	NOT USED		R-15	3-2-2	0.33 Ω , 5%, 2-watt
R7	NOT USED			3-14-2	(SP-2711)
R8	NOT USED			3-12-5	0.15 Ω , 5%, 2-watt
R9	NOT USED				(SP-2721)
R10	NOT USED				0.09 Ω , 5%, 5-watt
					(SP-2731)

CIRCUIT Component No.	PART No.	DESCRIPTION	CIRCUIT Component No.	PART No.	DESCRIPTION
Resistors (cont'd.)			CONTROLS		
R-16	1-1	47 Ω , 10%, 1/2-watt (SP-2701) NOT USED (SP-2711, SP-2721, SP-2731)	R21/R22	12-137	50 k Ω , 10 k Ω dual
R17	3-1-2	0.82 Ω , 5%, 2-watt (gray-red-silver) (SP-2701) NOT USED (SP-2711, SP-2721, SP-2731)	R23	10-269	2000 Ω (2K)
R-18		NOT USED	CAPACITORS		
R19		NOT USED	C1	21-72	5000 pF (.005 μ F), 1400V (1.4 kV) ceramic
R20	1-143	2.7 Ω , 5%, 1/2-watt (SP-2701)	C2	25-809	6000 μ F electrolytic (SP-2701, SP-2711)
R22	2-619-12	990 k Ω , 0.1%, 1/4-watt		25-296	20,000 μ F electrolytic (SP-2721)
	2-77-12	60 k Ω , 1%, 1/4-watt, 100 PPM/C precision (SP-2701)		25-297	70,000 μ F electrolytic (SP-2731)
R24	2-201	30 k Ω , 1%, 1/2-watt precision (SP-2711)	C3	25-809	6000 μ F electrolytic (SP-2701, SP-2711)
	2-97	25 k Ω , 1/2-watt precision (SP-2721)	C4-C10		NOT USED
	2-662-12	7500 Ω (7.5k), 1%, 1/4-watt, 100 PPM/C precision (SP-2731)	C11	2-156	470 pF ceramic
	2-208	111 k Ω , 1%, 1/2-watt precision (SP-2701)	C12-C20		NOT USED
	2-699-12	55 k Ω , 1%, 1/4-watt, 25 PPM/C precision (SP-2711)	C21	27-80	0.33 μ F Mylar (SP-2701)
R25	2-266	15 k Ω , 1%, 1/2-watt precision (SP-2721)		25-299	1.5 μ F electrolytic (SP-2711)
	2-50	10 k Ω , 1%, 1/2-watt precision (SP-2731)		25-39	2 μ F electrolytic (SP-2721)
	2-612-12	4870 Ω , 1%, 1/4-watt 100 PPM/C precision (SP-2701)	C22	25-147	10 μ F electrolytic (SP-2731)
R26	2-44-12	5000 Ω (5K), 1%, 1/4-watt, 100 PPM/C precision (SP-2711, SP-2721, SP-2731)	C23	27-72	0.1 μ F Mylar
R27	3-38-10	0.1 Ω , 0.5%, 10-watt		27-43	0.047 μ F Mylar (SP-2701)
R28	1-134	3.9 Ω , 5%, 1/2-watt	C28	27-72	0.1 μ F Mylar (SP-2711)
				27-60	0.22 μ F Mylar (SP-2721, SP-2731)
			DIODES		
			D1	57-46	DRS102 (SP-2701)
				57-42	3A1 (SP-2711)
			D2	57-46	DRS102 (SP-2701)
				57-42	3A1 (SP-2711)

CIRCUIT Component No.	PART No.	DESCRIPTION
Diodes (cont'd.)		
D1/D2	100-1644	Diode assembly (SP-2721, SP-2731)
D3-D10		NOT USED
D11	57-89	MR1122
D12-D20		NOT USED
D21	57-89	MR1122
D22	57-65	1N4002

TRANSISTORS

Q1	417-264	SJE608
Q2	{ 417-833	2N6306 (SP-2701, SP-2711)
	{ 417-139	40411 (SP-2721, SP-2731)
Q3	{ 417-833	2N6306 (SP-2701, SP-2711)
	{ 417-139	40411 (SP-2721, SP-2731)
Q4	417-833	2N6306 (SP-2701)
		NOT USED (SP-2711, SP-2721, SP-2731)

MISCELLANEOUS PARTS

	{ 54-862	Power transformer (SP-2701)
	{ 54-863	Power transformer (SP-2711)
T1	{ 54-864	Power transformer (SP-2721)
	{ 54-865	Power transformer (SP-2731)
SW1/SW4/	64-676	Pushbutton switch
SW5		assembly
SW2	60-54	Slide switch
SW3	61-22	Toggle switch
F1	421-1	1½ ampere, 250 volt fuse
F1	421-2	3 ampere, 125 volt fuse

CIRCUIT Component No.	PART No.	DESCRIPTION
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Control Circuit Board Components

RESISTORS

(All resistors are 5%, ½-watt unless otherwise specified.)

R101	1-145	47 Ω
R102	1-52	680 Ω
R103	1-151	330 Ω
R104	1-52	680 Ω
R105-R110		NOT USED
R111	1-33	15 kΩ
R112	1-147	220 Ω
R113	2-3-12	845 Ω, 1%, ¼-watt, 25 PPM/C precision
R115	1-158	2700 Ω
R117	1-52	680 Ω
R118	1-114	8200 Ω
R119	157	470 Ω
R120		NOT USED
R121	1-146	75 Ω
R122	1-52	680 Ω
R123	1-114	8200 Ω
R124	1-52	680 Ω
R125		NOT USED
R126	1-66	150 Ω, 10%
R127	1-33	15 kΩ
R128	1-151	330 Ω
R129	1-157	470 Ω
R130		NOT USED
R131	1-157	470 Ω
R132		NOT USED
R133	1-51	6800 Ω
R134	1-51	6800 Ω
R136	1-43	4700 Ω
R137	1-43	4700 Ω
R138	1-144	1800 Ω

CIRCUIT Component No.	PART No.	DESCRIPTION
Resistors (cont'd.)		
R139	1-43	4700 Ω
R140		NOT USED
R141		NOT USED
R142	2-638-12	22.22 k Ω , 1%, 1/4-watt, 100 PPM/C precision (SP-2701)
	1-66-12	10 k Ω , 1%, 1/4-watt, 100 PPM/C precision (SP-2711)
	2-718-12	4000 Ω , (4K), 1/4-watt, 100 PPM/C precision (SP-2721)
	2-56-12	1000 Ω (1K), 1%, 1/4-watt, 100 PPM/C precision (SP-2731)
R143	2-60-12	2000 Ω , (2K), 1%, 1/4-watt, 100 PPM/C precision
R144-R150		NOT USED
R151	1-133	15 k Ω
R153	1-37	2.2M Ω , 10%
R154	1-37	2.2 M Ω , 10%
R155	1-89	2400 Ω
R156	1-89	2400 Ω
R158	3-38-10	0.1 Ω , .5%, 10-watt precision (SP-2701, SP-2711, SP-2721)
R158	3-46-5	0.01 Ω , .5% 5-watt precision (SP-2731)
R159	1-58	22 k Ω
R160		NOT USED
R161	1-151	330 Ω

CIRCUIT Component No.	PART No.	DESCRIPTION
CONTROLS		
R114	10-904	5000 Ω (5K)
R116	10-390	20 k Ω
R135	10-917	200 Ω
R152	10-946	500 k Ω
R162	10-390	20 k Ω

CAPACITORS

C101	25-248	100 μ F electrolytic
C102-C110		NOT USED
C111	25-248	100 μ F electrolytic
C112	21-176	.01 μ F ceramic
C113-C114		NOT USED
C115	25-248	100 μ F electrolytic
C116	21-176	.01 μ F ceramic
C117	21-144	4700 pF (.0047 μ F) ceramic
C118-C120		NOT USED
C121	21-176	.01 μ F ceramic
C122	21-173	2200 pF (.0022 μ F) ceramic
C123-C125		NOT USED
C126	21-173	2200 pF (.0022 μ F) ceramic
C127		NOT USED
C128	21-21	200 pF ceramic
C129	21-111	15 pF ceramic (SP-2701)
	21-84	24 pF ceramic (SP-2711)
	21-32	47 pF ceramic (SP-2721)
	21-96	85 pF ceramic (SP-2731)
C130-C140		NOT USED
C141	21-9	100 pF ceramic
C142-C150		NOT USED
C151	21-6	27 pF ceramic
C152	21-171	680 pF ceramic

DIODES

D101	57-65	1N4002
D102	57-65	1N4002
D103	56-58	1N709A, 6.2-volt zener

CIRCUIT Component No.	PART No.	DESCRIPTION
D104-D110		NOT USED
D111	57-65	1N4002
D112	57-65	1N4002
D113	56-59	1N750A, 4.7-volt zener
D114	56-57	1N716S, 12-volt zener
D115	56-71	1N825A, 6.2-volt temperature-compensated zener

D116	57-65	1N4002
D117	57-65	1N4002
D118	56-57	1N716A, 12-volt zener
D119	56-63	MZ500 -10, 5.6-volt zener

D120		NOT USED
D121	56-56	1N4149
D122	56-56	1N4149
D123	56-56	1N4149
D124-D130		NOT USED
D131	56-63	MZ500-10, 5.6-volt zener

D132-D150		NOT USED
D151	56-56	1N4149
D152	56-56	1N4149
D153	56-56	1N4149
D154	57-65	1N4002
D155-D160		NOT USED
D161	56-63	MZ500-10, 5.6-volt zener
D162	56-56	1N4149

TRANSISTORS-INTEGRATED CIRCUIT

Q101	417-295	MPSL51
Q102	417-201	X29A829
Q103	417-801	MPSA20
Q104	417-201	X29A829
Q105	417-201	X29A829
Q106	417-294	MPSA42
Q107	417-294	MPSA42
Q108	417-201	X29A829
Q109	417-201	X29A829
Q110/Q111	117-12	Matched <u>transistor pair</u>
Q112	417-801	MPSA20
Q113	417-294	MPSA42
IC101	442-22	741 integrated circuit

CIRCUIT Component No.	PART No.	DESCRIPTION
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Display Power Supply Circuit Board Components

RESISTORS

1/2-watt, 5% (unless otherwise specified)

R201	1-20	10 k Ω , 10%
R202	1-20	10 k Ω , 10%
R203	1-60-1	330 Ω , 1-watt
R204	1-131	620 Ω
R205	1-51	6800 Ω
R206	1-114	8200 Ω
R207-R210		NOT USED
R211	1-2-1	1000 Ω , 10%, 1-watt
R212	3-7-2	1.0 Ω , 10%, 2-watt
R213	1-131	620 Ω
R214	1-23	100 Ω
R215	1-131	620 Ω
R216	1-174	33 Ω
R217	1-20	10 k Ω , 10%
R218	1-20	10 k Ω , 10%
R219-R220		NOT USED
R221-R222	100-1636	Part of calibration assembly
R223		
R224	1-57	2200 Ω
R225	1-97	1100 Ω

CAPACITORS

C201	21-16	0.01 μ F ceramic
C202	25-812	3000 μ F electrolytic
C203	25-234	500 μ F electrolytic
C204	21-16	0.01 μ F ceramic
C205	21-16	0.01 μ F ceramic
C206	25-212	22 μ F tantalum
C207	25-234	500 μ F electrolytic
C208	21-16	0.01 μ F ceramic
C209-C210		NOT USED
C211	21-16	0.01 μ F ceramic
C212	21-16	0.01 μ F ceramic

CIRCUIT Component No.	PART No.	DESCRIPTION	CIRCUIT Component No.	PART No.	DESCRIPTION
DIODES			Resistors (cont'd.)		
D201	56-89	GD510	R315	1-76-12	4700 Ω
D202	56-89	GD510	R316	1-76-12	4700 Ω
D203	57-27	IN2071	R317	1-76-12	4700 Ω
D204	57-27	IN2071	R318-R320		NOT USED
D205	57-65	IN4002	R321	1-76-12	4700 Ω
D206	57-65	IN4002	R322	1-76-12	4700 Ω
D207-D210		NOT USED	R323	1-91-12	22 k Ω
D211	57-65	IN4002	R324	1-91-12	22 k Ω
D212	57-65	IN4002	R325	2-658-12	2210 Ω (2.21k), 1.00%, 100 PPM/C
D213	57-65	IN4002	R326	2-658-12	2210 Ω (2.21k), 1.00%, 100 PPM/C
D214	57-65	IN4002	R327	10-294	2000 Ω (2k) control
D215		NOT USED	R328	1-91-12	22 k Ω
D216	56-25	IN4166A, 15-volt zener	R329-R330		NOT USED
D217	56-91	IN823, 6.2-volt zener	R331	10-936	1000 Ω (1k) control
D218	56-612	IN5229, 4.3-volt zener	R332	2-50-12	80.6 Ω , 1.00%, 100PPM/C
D219	100-1636	Part of calibration assembly	R333	2-3-11	211.7 Ω , 1/8-watt, 1.00%, 100 PPM/C
TRANSISTORS			R334	1-76-12	4700 Ω
Q201	417-818	MJE181	R335	1-76-12	4700 Ω
Q202	417-801	MPSA20	R336	1-76-12	4700 Ω
Q203	417-801	MPSA20	R337	1-91-12	22 k Ω
Q204	417-294	MPSA42	R338	1-91-12	22 k Ω
Q205	417-801	MPSA20	R339	1-99-12	1800 Ω
Q206	417-801	MPSA20	R340		NOT USED
Display Circuit Board Components			R341	2-34-12	15 k Ω , 1.00%, 100 PPM/C
RESISTORS			R342	1-91-12	22 k Ω
1/4-watt, 5% (unless otherwise specified)			R343	1-91-12	22 k Ω
R301	2-39-12	10 k Ω , 0.1%, 25 PPM/C	R344	1-91-12	22 k Ω
R302	1-126-12	5.1 Ω	R345	1-60-12	100 Ω
R303	1-84-12	100 k Ω	R346	1-64-12	390 Ω
R304	10-904	5000 Ω (5k) control	CAPACITORS		
R305	1-91-12	22 k Ω	C301	25-212	22 μ F tantalum
R306	2-64-12	6650 Ω (6.65k), 1.00%, 100 PPM/C	C302	25-276	4.7 μ F tantalum
R-307	1-76-12	4700 Ω	C303	21-13	500 pF ceramic
R308	1-87-12	1M Ω	C304	25-220	10 μ F tantalum
R309-R311		NOT USED	C305	21-167	39 pF ceramic
R312	1-88-12	10 M Ω , 10%	C306	29-12	0.5 μ F polycarbonate
R313	1-88-12	10 M Ω , 10%	C307	21-36	2000 pF (0.002 μ F) ceramic
R314	1-72-12	2200 Ω	C308	21-36	2000 pF (0.002 μ F) ceramic
			C309	21-36	2000 pF (0.002 μ F) ceramic
			C310	21-140	1000 pF (0.001 μ F) ceramic

CIRCUIT Component No.	PART No.	DESCRIPTION
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Capacitors (cont'd.)

C311	21-176	0.01 μ F ceramic
C312	21-176	0.01 μ F ceramic
C313	25-220	10 μ F tantalum
C314	21-176	0.01 μ F ceramic

DIODES

D301	56-56	IN4149
D302	56-89	GD510

TRANSISTORS

Q301	417-801	MPSA20
Q302	417-235	2N4121
Q303	417-294	MPSA42
Q304	417-801	MPSA20
Q305	417-801	MPSA20
Q306	417-235	2N4121
Q307	417-294	MPSA42
Q308	417-801	MPSA20
Q309	417-294	MPSA42

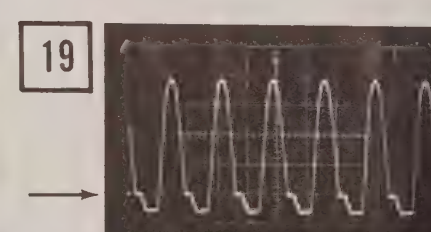
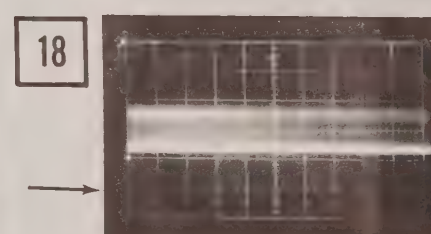
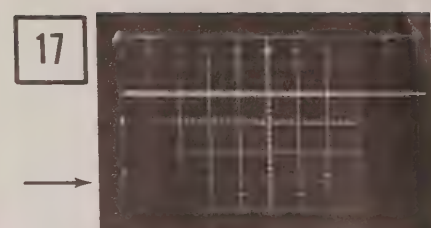
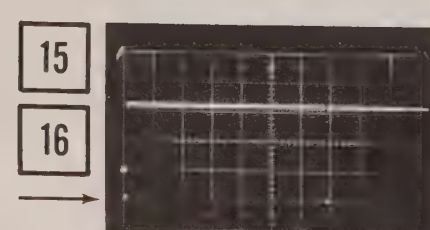
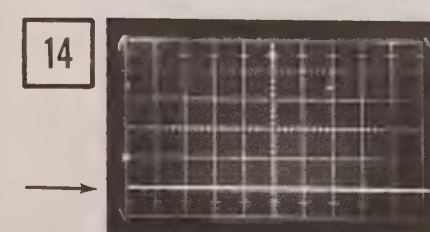
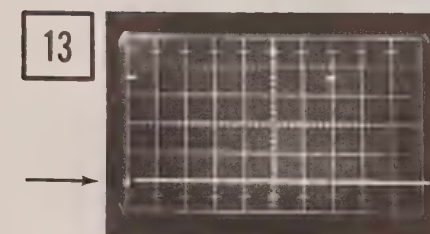
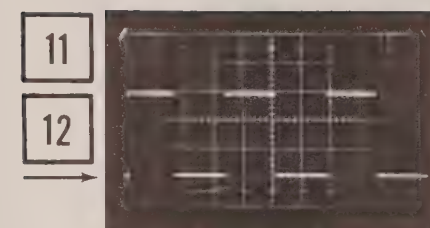
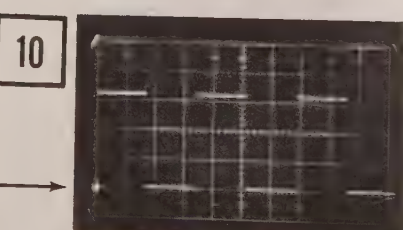
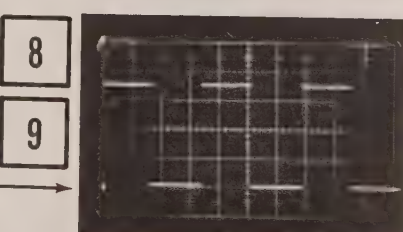
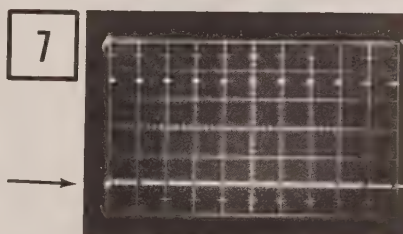
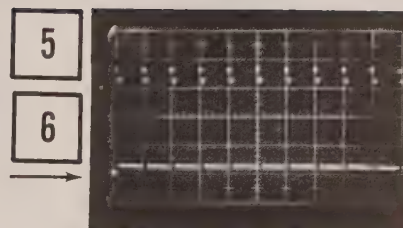
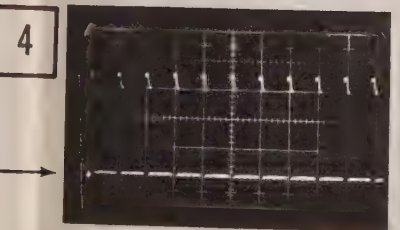
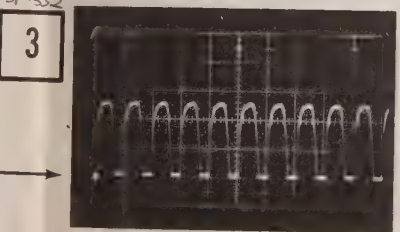
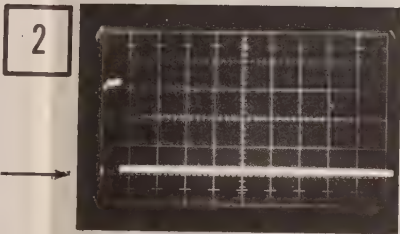
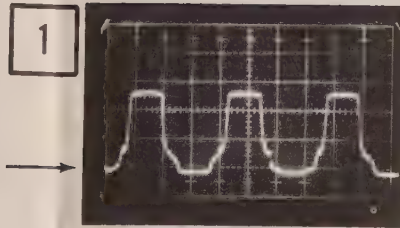
CIRCUIT Component No.	PART No.	DESCRIPTION
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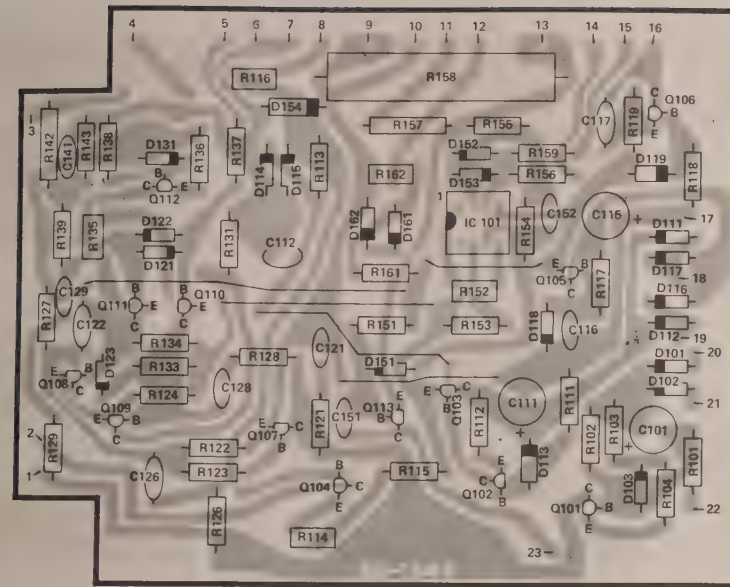
INTEGRATED CIRCUITS

IC301	443-7	7490
IC302	443-602	DD700 (DM8880)
IC303	443-7	7490
IC304	443-602	DD700 (DM8880)
IC305	443-7	7490
IC306	443-602	DD700 (DM8880)
IC307	443-7	7490
IC308	443-18	7404
IC309	443-3	7430
IC310	443-12	7410
IC311	443-1	7400
IC312	443-7	7490
IC313	443-1	7400
IC314	443-695	4001 (caution MOS device)
IC315	442-99	4016 (caution MOS device)
IC316	442-75	311
IC317	442-39	301

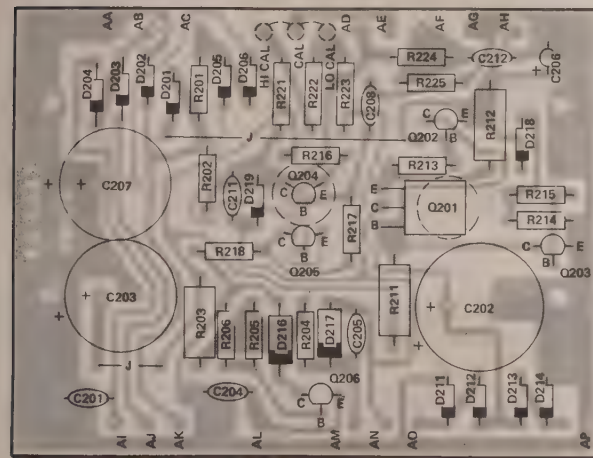
MISCELLANEOUS

L301	40-487	300 μ H coil
V301	411-295	Display tube 700 Beckman SP-352
V302	411-295	Display tube

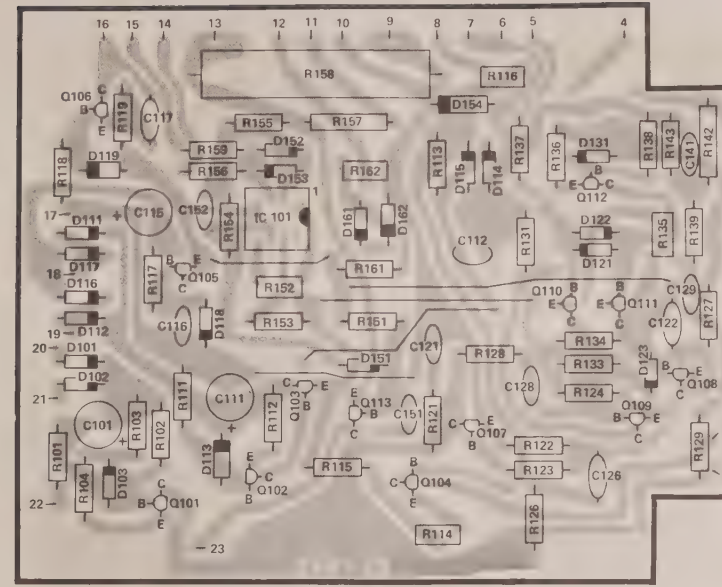




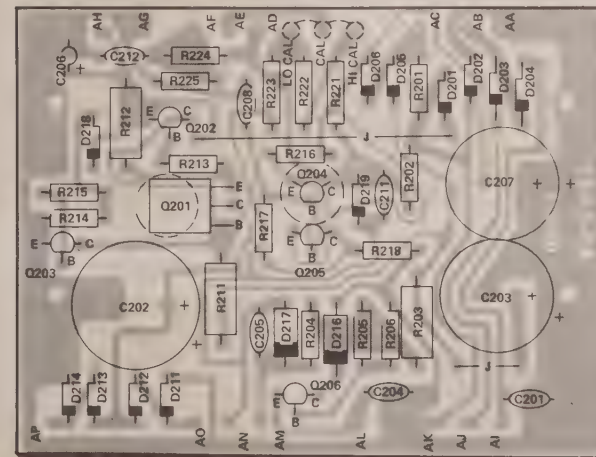
CONTROL CIRCUIT BOARD
(Viewed from foil side)



DISPLAY POWER SUPPLY CIRCUIT BOARD
(Viewed from foil side)

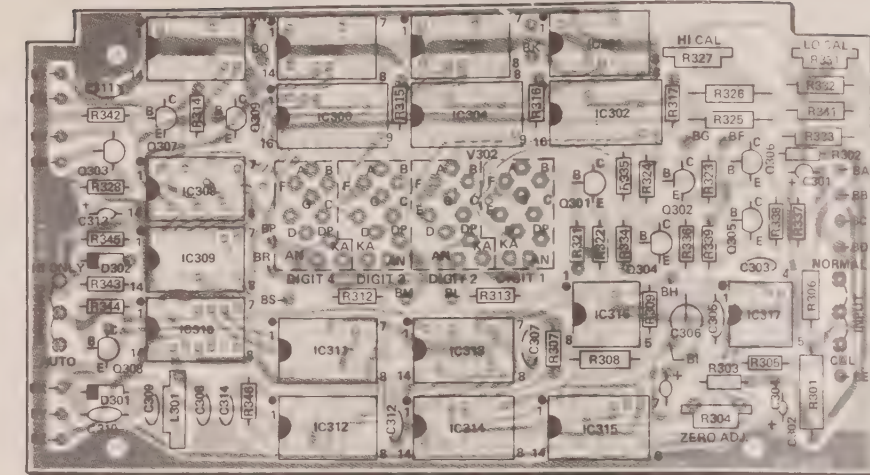


CONTROL CIRCUIT BOARD
(Viewed from component side)

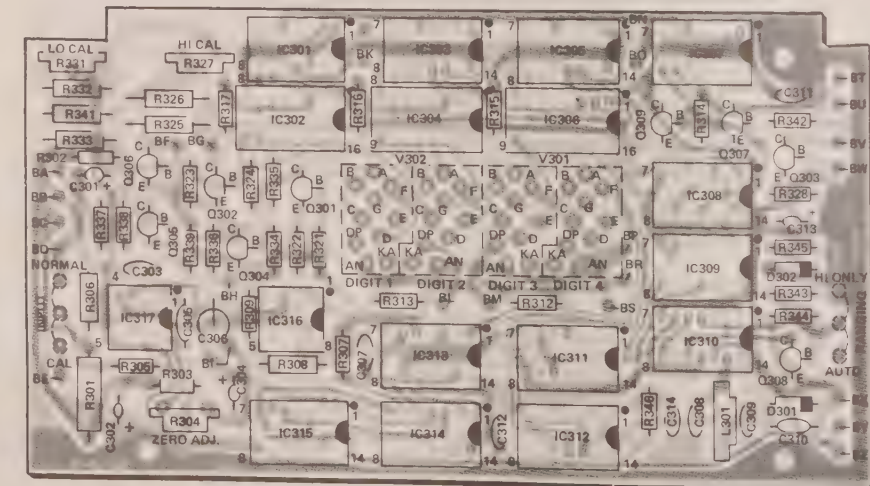


DISPLAY POWER SUPPLY CIRCUIT BOARD
(Viewed from component side)

CIRCUIT BOARD X-RAY VIEWS



DISPLAY CIRCUIT BOARD
(Viewed from foil side)



DISPLAY CIRCUIT BOARD
(Viewed from component side)

EXPEDITED PARTS ORDER FORM

(FOR REPAIR PARTS ONLY)

PLEASE DO NOT WRITE IN THIS SPACE

NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

KIT MODEL

PURCHASE DATE

INVOICE NUMBER

LOCATION PURCHASED

SEND TO: **HEATH COMPANY**

BENTON HARBOR,

MICHIGAN 49022

ATTN PARTS REPLACEMENT

QTY.	HEATH PART NUMBER	DESCRIPTION OF PART	PRICE	TOTAL PRICE	DESIRED METHOD OF SHIPMENT

INSTRUCTIONS:

- INCLUDE CHECK OR MONEY ORDER FOR TOTAL PARTS ORDERED ADD 10% (MINIMUM \$0.25) FOR INSURANCE, POSTAGE AND HANDLING.
- AUTHORIZE PERMISSION FOR C.O.D. SHIPMENT (MINIMUM ORDER SHIPPED C.O.D. IS \$10.00).
- MICHIGAN RESIDENTS ADD 4% SALES TAX

C.O.D. AUTHORIZATION

SIGNED _____

THIS FORM IS FOR U.S. CUSTOMERS ONLY. OVERSEAS CUSTOMERS SEE YOUR DISTRIBUTOR.

CUT ALONG DOTTED LINE

EXPEDITED PARTS ORDER FORM

(FOR REPAIR PARTS ONLY)

PLEASE DO NOT WRITE IN THIS SPACE

NAME _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

KIT MODEL

PURCHASE DATE

INVOICE NUMBER

LOCATION PURCHASED

SEND TO: **HEATH COMPANY**

BENTON HARBOR,

MICHIGAN 49022

ATTN PARTS REPLACEMENT

QTY.	HEATH PART NUMBER	DESCRIPTION OF PART	PRICE	TOTAL PRICE	DESIRED METHOD OF SHIPMENT

INSTRUCTIONS:

- INCLUDE CHECK OR MONEY ORDER FOR TOTAL PARTS ORDERED ADD 10% (MINIMUM \$0.25) FOR INSURANCE, POSTAGE AND HANDLING.
- AUTHORIZE PERMISSION FOR C.O.D. SHIPMENT (MINIMUM ORDER SHIPPED C.O.D. IS \$10.00).
- MICHIGAN RESIDENTS ADD 4% SALES TAX

C.O.D. AUTHORIZATION

SIGNED _____

THIS FORM IS FOR U.S. CUSTOMERS ONLY. OVERSEAS CUSTOMERS SEE YOUR DISTRIBUTOR.

SERVICE INFORMATION

The following Heath Company services are available if you need them: Replacement Parts, Technical Consultation, and Factory Service. Address all correspondence to:

HEATH COMPANY

Benton Harbor, Michigan 49022

For prompt service, use a separate letter for each department you write to.

Replacement parts and repair service are also available at your nearest Authorized Service Center or Heath Electronic Center. These Centers are listed in your Heath Catalog.

REPLACEMENT PARTS

If a replacement part is needed, please include the following information in your letter:

1. Part number and description.
2. Model Number and Series Number of the equipment.

If your equipment is in the Warranty period, add:

3. Date of purchase.
4. Nature of defect.

Heath Company will fill your order promptly. Please **DO NOT RETURN PARTS** unless they are requested. Parts that are damaged through carelessness or misuse by the customer will not be replaced without cost.

TECHNICAL CONSULTATION

You can write to our Technical Consultants for help with any Heath equipment, or for answers to any questions about the use of this equipment.

The completeness and accuracy of the advice mailed back to you depends entirely on the information in your letter. Be sure to include:

1. The Model Number and Series Number of the equipment (on blue and white identification label).
2. Date of purchase.

3. An exact description of the difficulty. Include switch positions, connections to other units, operating procedures, voltage reading, and any other information you think might be helpful.
4. List everything you have done in attempting to correct the difficulty.

FACTORY SERVICE

If you do not have qualified repair services at your disposal, you can return your equipment to the Heath Company Service Department to have it repaired for a minimum service fee. (Equipment that has been modified will not be accepted for repair.) Refer to Shipping Instructions for details on how to package and ship the equipment.

To be eligible for replacement parts under the terms of the Warranty, equipment returned for factory service must be accompanied by the invoice or the sales slip, or a copy of either. (If you send the original invoice or sales slip, it will be returned to you.)

SHIPPING INSTRUCTIONS

Check the equipment to see that all parts are in place. Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least three inches of resilient packing material (shredded paper, excelsior, etc.) on all sides between the equipment and the carton.

Seal the carton with gummed paper tape and tie it with a strong cord. Ship it by prepaid Express or insured Parcel Post to:

HEATH COMPANY

Benton Harbor, Michigan 49022

Attach a letter, containing the following information to the outside of the carton:

1. Your name and return address.
2. Date of purchase.
3. A brief description of the difficulty.
4. Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the Warranty.

YOUR HEATH ASSEMBLED PRODUCT ONE-YEAR FULL WARRANTY

During your first year of ownership, any factory-assembled unit that fails to meet published specifications will be serviced free of charge -- as soon as practical -- upon delivery at your expense to the Heath factory, or to any Heathkit Electronic Center (units of Schlumberger Products Corporation).

The serviced unit will be returned to you at our expense anywhere in the continental United States or to APO or FPO addresses.

You will receive free consultation on any problem you might encounter in the use of your Heath assembled product. Just drop us a line or give us a call. Sorry, we cannot accept collect calls.

Our warranty, both expressed and implied, does not cover damage caused by misuse, fire, customer-made modifications, flood or acts of God, nor does it include reimbursement for customer setup or down time. The warranty covers only Heath products and is not extended to non-Heath allied equipment used in conjunction with our products or uses of our products for purposes other than as advertised.

And if you are dissatisfied with our service -- warranty or otherwise -- or our products, write directly to our Director of Customer Services, Heath Company, Benton Harbor, Michigan 49022. Telephone (616) 982-3524. He'll make certain your problems receive immediate, personal attention.

HEATH COMPANY
BENTON HARBOR, MI. 49022

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

www.manualsplus.com



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